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Sinus floor elevation via hydraulic detachment and elevation of the Schneiderian membrane

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Key words: autogenous bone graft, bone augmentation, bony kernel, hydraulic detachment, hydraulic elevation, trephine burr

Abstract

Objectives: Minor sinus floor elevation is a method with relatively high predictability but is technically demanding. Improvement of the technique and increase in the predictability are desirable.

Material and methods: A clinical protocol for minor sinus floor elevation with SLA®-ITI® (large grit acid-etched implants with diameter of 4.8 mm) is described. Using trephine instead of spiral burrs enables the harvesting of autogenous grafts from the implant socket and guarantees a perfect implant socket. The latter is necessary for optimal implant anchoring and for the hydraulic seal between socket and the osteotome. The whole allows a hydraulic detachment of the Schneiderian membrane, where the blood cushion gradually detaches and elevates the membrane, preventing its contact with the graft.

Results: Eight patients were successfully treated with the method described above. No membrane perforation occurred and an uneventful healing was observed in all patients. All implants were loaded prosthodontically 3 months after the implantation.

Conclusions: The clinical protocol presented provides high predictability in clinical outcome, together with extremely low morbidity and shortened surgery.

Sinus floor elevation (SFE) allows predictable implant insertion in the deficient posterior maxilla. An alternative to the most commonly used lateral (major) window approach involves the apical displacement of crestal bone using the osteotome technique (Horowitz 1997; Zitzmann & Scharer 1998; Rosen et al. 1999; Nkenke et al. 2002b). Minor maxillary SFE incorporates specially designed osteotomes to minimise the incidence of membrane perforation and placement of a graft over the core osteotomy. A surgical mallet is used to tap the osteotome handle. The force applied should be sufficient to fracture the sinus cortical floor but restrained enough to prevent the osteotome tip from traumatising the Schneiderian membrane. However, tapping the remaining bone of the sinus floor holds the danger of perforation of the sinus membrane. Although this technique is less invasive than the lateral window technique, it cannot be recommended as a standard procedure in the posterior maxilla because of the technically demanding procedure. Also, membrane detachment and elevation with a blunt elevator after osteotomy cannot prevent perforations (Nkenke et al. 2002b).

To achieve highly predictable bone augmentation, various clinicians have used autogenous bone grafts (Cordaro 2003; Merkx et al. 2003; Pinholt 2003). Intraoral bone grafts from the mandible are a con-

venient source of autogenous bone. However, harvesting bone grafts from the mandible is associated with morbidity (Nkenke et al. 2002a; Clavero & Lundgren 2003) and possible complications occurring at the intraoral donor sites – decreased sensitivity with permanent altered sensation, haematoma, weakening of the bony frame etc. (Hallman 2002; Clavero & Lundgren 2003). Thus, a method for minor SFE with high predictability (reduced risk for membrane perforation) and low morbidity (graft harvesting from the implant site) is required.

This study offers a clinical protocol for minor SFE, recommendable as a standard procedure in the posterior maxilla and enabling a simultaneous harvest of autogenous bone graft from the implant socket.

Material and methods

Patient selection

Patients needing a reconstruction of upper molars with a maxillary crest height of 6–9 mm and a maxillary crest width of minimum 8 mm were selected. The measurement of the maxillary crest height was performed via orthopantomographs and that of the maxillary crest width via a pair of bone callipers (Medesy, Miniago, Italy) under local anaesthesia.

Exclusion criteria recommended previously (Buser et al. 2000) were used. In addition, patients were excluded if they exhibited pathological findings or had a history of maxillary sinus diseases or operations.

The endosteal implants and xenogenic bone substitute material used were SLA®-ITI® Wide Neck Implants, diameter 4.8 mm and length 10 mm (Straumann, Waldenburg, Switzerland), and bovine hydroxyapatite (Bio-Oss®, Geistlich Pharmaceutical, Wollhausen, Switzerland).

Clinical protocol

A crestal gingiva incision was made, raising full mucoperiostal flap. The incision was extended in the buccal and palatal directions through the sulcus of the neighbouring teeth, but without any buccal relieving incision or coronal advancing. The full mucoperiostal flap was mobilised, but the maxillary crest was not planed to keep the cortical lamina intact. An ITI® trephine burr for explantation of ITI® Narrow Neck implants with the outer diameter of 4.2 mm modified via semicircular cooling holes (Fig. 1) was used to cut the implant socket and simultaneously to cut out a bony kernel. The trephine was drilled nearly two mm short of the calculated available bone height and an intraoperative X-ray picture was taken with the trephine *in situ* as a gauge to estimate more exactly the remaining distance to the sinus floor. Subsequently, the trephine was stopped nearly 1 mm from the sinus floor. The moulded kernel was broken off using a root elevator of similar type to that employed in tooth extraction. Three cracking modes of the kernel are possible (Figs 2–4). If the kernel remains attached to the Schneiderian membrane only (Fig. 2), it can be gripped with diamond tweezers, tilted as far as possible in all directions, slightly rotated and simultaneously gently pulled out of the socket. If the kernel should break directly at the trephine cutting line, a fracture of the sinus bone floor via osteotome remains possible (Fig. 3). If the kernel breaks under the trephine cutting line (Fig. 4), the kernel rest should be drilled with a 3.5 mm spiral burr and then the sinus floor fractured with an osteotome (ITI® osteotome Straumann, Waldenburg, Switzerland) with diameter of 4.2 mm using a mallet to tap. The depth stop of the osteotome is fixed at 2 mm more than the height of the implant socket; hence an apical advance of 2 mm more than the socket length was made in all manipulations with the osteotome.

After removing a full kernel or the fracture of the sinus bone floor, the surgeon should wait until the implant socket is filled in with blood (Fig. 5) and then use the osteotome as a piston and the blood as both a sealing and hydraulic medium, gra-

Fig. 1. ITI® explantation trephine burrs with outer diameter of 4.2 mm provided with semicircular holes. The latter have two functions – to enable a sufficient cooling and to allow the trephine to be used as a gauge in intraoperative X-ray pictures.

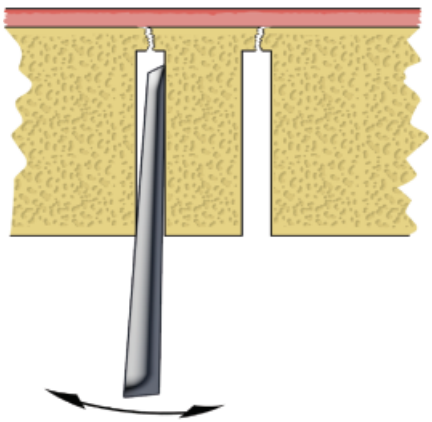

Fig. 2. A full bony kernel.

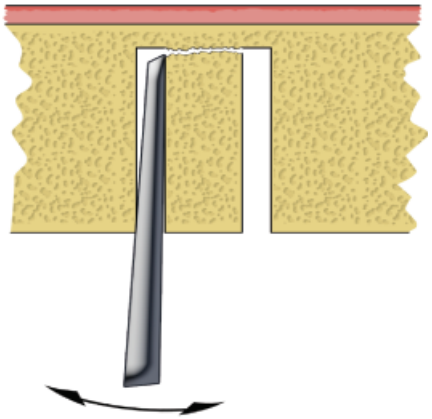

Fig. 3. A kernel fractured directly at the trephine cutting line.

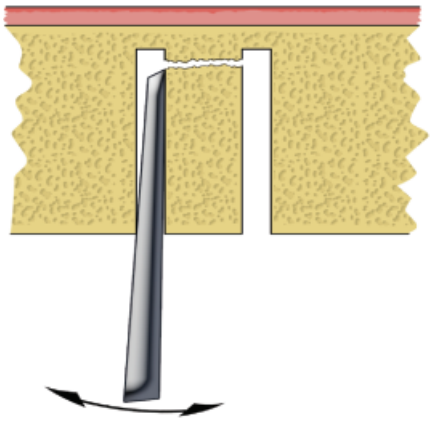

Fig. 4. A kernel fractured below the trephine cutting line.

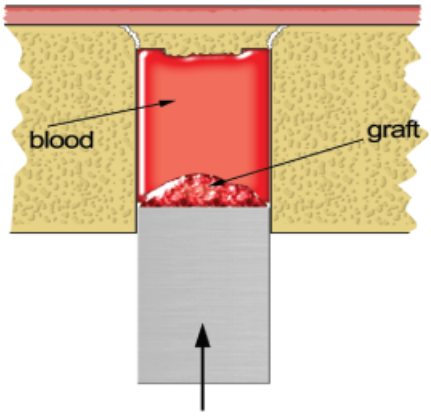

Fig. 5. Hydraulic detachment and initial elevation of the Schneiderian membrane. The osteotome acts as a piston and the blood as both sealing and fluid medium. After the socket is filled with blood from the walls, the osteotome is pushed into it and pumps in nearly 100 mm^3 of blood.

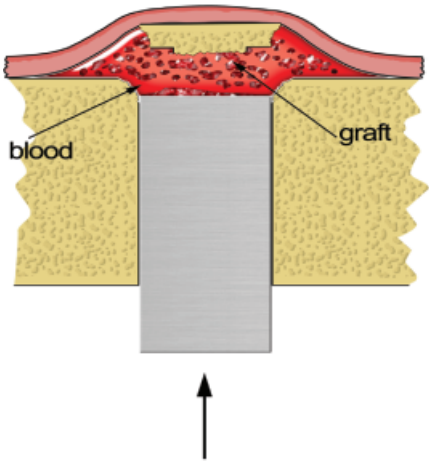

Fig. 6. The blood pumped in via the osteotome balloons the membrane causing its detachment and holds it up in a hemisphere. The osteotome is pushed 2 mm or less over the height of the implant socket. The blood cushion preserves contact of the membrane with the graft.

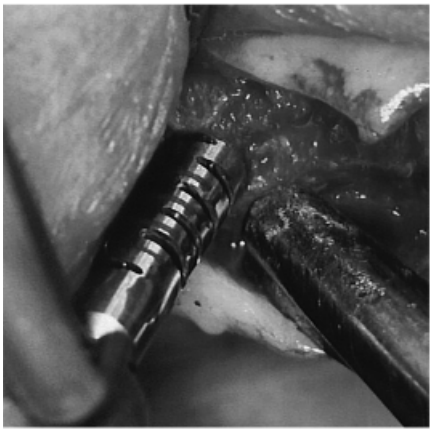

Fig. 7. Handling of the trephine burr: any flattening or scalloping of the maxillary crest must be avoided, if a sufficient intermaxillary distance is available.

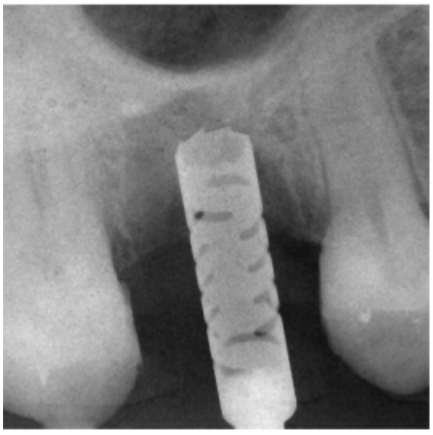

Fig. 8. An intraoperative X-ray picture with a trephine *in situ*. The semicircular holes of the trephine enable its use as a gauge.

dually increasing the hydraulic pressure in the implant socket. This handling avoids the membrane coming into contact with hard objects, which can cause perforation. The osteotome is manipulated with one hand only and is rotated continuously to reduce the friction. It is slowly pushed apically. The depth stop of the osteotome remains adjusted as before; thus, each movement of the osteotome will pump in a blood volume of a cylinder of at least 8 mm length and 4.2 mm diameter (nearly 100 mm^3). The Schneiderian membrane must be left intact, since it provides a barrier similar to the guided-tissue membranes used in bone-grafting procedures. The desired effect is one of a dome. The blood pumped in should balloon the membrane causing its detachment and hold it up in a hemisphere (Fig. 6). The bony kernel can be divided with a bone rongeur Luer into at least four discs with a width of approximately 1.5 mm. A total of 100 mm^3 of Bio-Oss® mixed with nearly the same quantity of autogenous bone is pushed into the socket. A kernel disc (or a half kernel disc) is placed into the concavity of the osteotome together with the Bio-Oss® and pushed apically with the osteotome. In this manipulation, the osteotome acts again as a piston and the blood cushion precedes the substitute, so that the substitute does not press directly against the membrane (Fig. 5). The osteotome is advanced apically 2 mm more than the length of the socket. This procedure needs to be repeated at least four times. Then the implant is screwed into the desired position, i.e. 1 to 4 mm beyond the initial sinus floor depending on the maxillary crest height.

Treatment of the posterior maxilla was carried out under local anaesthesia with 2 ml Ultracain® dental forte (Aventis Pharma Deutschland GmbH, Frankfurt am Main, Germany). No sedation was used. Medication with the wide spectrum antibiotic Vibramycin® 200 mg (Pfizer Corporation Austria GmbH, Vienna, Austria) was given 2 h before surgery. Further, the antibiotic coverage was maintained for 9 days. An additional postoperative treatment comprised a maximum of three or less intakes of 400 mg ibuprofen (Ibumetin® forte, Nycomed Austria GmbH, Linz, Austria) at intervals of nearly 8 h. No type of decongestant medication was administered. Prosthodontic treatment was performed 3 months postoperatively.

Results

Eight patients (two females and 6 males, in the age group 35–49 years (mean 42 years)) were treated with the above method for minor SFE. The residual vertical bone height ranged between 6 and 8 mm (average 6.75 mm). After drilling with trephine burr to within nearly 2 mm of the sinus floor (Fig. 7), intraoperative X-ray pictures were taken with the trephine *in situ* as a gauge (Fig. 8). Subsequently, drilling was continued 1 mm deeper. The kernel extraction was made, depending on the break modus, with tweezers (in two cases) or with root elevator (Fig. 9). No damage of the socket wall as a result of the kernel extraction was observed. If the kernel was broken too high and the rest of it could not be safely removed with the aid of a root elevator, it was removed with a 3.5 mm spiral burr. All further manipulations were performed as described in the clinical protocol.

Although only 0.2 cm^3 of bone graft (Fig. 10) was inserted under the membrane, a dome over the implant of considerably larger volume (depending on the number of the osteotome pumping insertions) was observed in the orthopantomograph (Fig. 11). The control X-rays revealed a dome-like elevation of the X-ray contrast over the

Fig. 9. The extracted kernel and a gauge with diameter of 4.2 mm for comparison.

Fig. 10. Autogenous and xenogenous graft placed on the osteotome.

implant and there were no signs indicating any membrane perforation. The implant insertion and the flap closure were uncomplicated. The postoperative healing period proceeded uneventfully in all cases. A follow-up radiological examination after 6 months revealed no pathological findings, and there were signs of successful ossification in the dome-like SFE in all patients (Fig. 12). The abutments were mounted with a torque of 35 N cm without causing any negative sensations in the patients. No implant mobility was observed. The prosthodontic loading took place a week later.

Discussion

Sufficient initial anchorage of the inserted implants is the crucial criterion for their successful osteointegration and hence for their survival. A properly inserted ITI® implant with SLA® surface and only 6 mm length provides a high reverse-torque value of 104.66 N cm, which is more significant than that of a 10 mm long Brånemark implant (Bernard et al. 2003). Thus, comparison of implants in human bone grafted maxilla has shown a higher overall survival rate of SLA®-ITI® (98%) rather than Brånemark (81%) implants (Pinholt 2003).

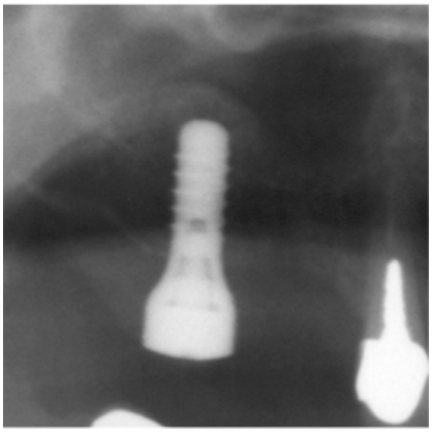

Fig. 11. An orthopantomograph with the inserted implant. The bone augmentation mixture of Bio-Oss® and autogenous bone is clearly visible as a hemispherical shadowing. Nearly 100 mm³ of autogenous bone and 100 mm³ of Bio-Oss® are used and the osteotome penetrates into the sinus space to a depth of 2 mm. Eight osteotome pumping insertions were made, and the graft is low X-ray-contrasted. Each pumping conveys nearly 200 mm³ graft, but the largest part of it is blood. The larger volume of the domed elevation indicates clearly the hydraulic rise of the membrane.

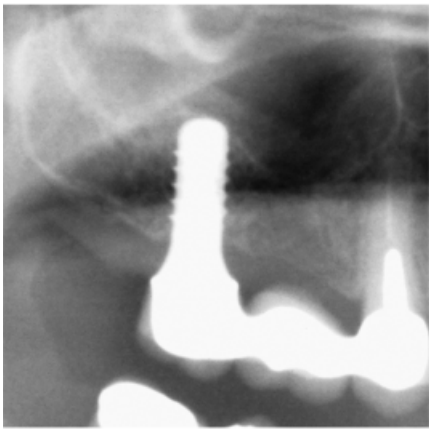

Fig. 12. A follow-up radiological examination of the implant shown in Fig. 11 six months later. Despite some resorption of the graft, the entire implant is surrounded by a newly formed bone, which cannot radiologically be distinguished from the residuary bone.

Given the surface (s) of ITI® implants is crucial for their survival ($s = 2\pi rl$, where r is the inner implant radius and l is the length of the implant), SLA®-ITI® implants with diameter of 4.8 mm should have only 6.7 mm length to reach the same survival rate as SLA®-ITI® implants (over 99%) (Cochran et al. 2002) with length of 8 mm and diameter of 4.1 mm. Hence, the use of SLA®-ITI® implants with diameter of 4.8 may be regarded as a very convenient way to achieve sufficient primary stability and hence to increase the survival rate. An SLA®-ITI® implant with diameter of 4.8 and 6 mm length should be equivalent to an SLA®-ITI® implant with diameter of 4.1 and 7.2 mm length. The high long-term survival rate of 6 mm ITI® implants (94%) (Bruggenkate et al. 1998) and that of 8 and 10 mm SLA®-ITI® implants with diameter of 4.1 mm (over 99%) (Cochran et al. 2002) suggest that an equivalent high survival rate of a virtual SLA®-ITI® implant with diameter of 4.1 mm and length of a minimum of 7.2 mm may be expected, independent of the maxillary augmentation above the inserted implant. Analysing the implant stability in the atrophic posterior maxilla with a three-dimensional model, Tepper et al. (2002) found that with short thick implants the overall stiffness of the bone-implant system is higher than with long, thin implants and displacements during loading are less extensive.

An additional factor contributing to better initial implant anchoring is the maintenance of the cortical bone. The absence of cortical bone had a clearly negative effect on interfacial stresses. These stresses are increased by 10% at the point of implant emergence in the sinus (Tepper et al. 2002). The cortical bone also enables the elevation of the bony kernel without damaging the socket walls and thus guarantees the seal necessary for creation of hydraulic pressure for the membrane detachment and elevation.

Another factor influencing the primary anchoring of an implant is the exactness of the socket preparation. Using spiral burrs, the slightest axial deviation can compromise the socket outline. By contrast, an ITI® explantation trephine burr cannot deform the socket outline. Thus, the use of trephine instead of spiral burrs is a very important factor improving the initial anchoring, and hence also the predictability.

The next key factor is the reduction of the tapping on the sinus floor by the osteotome from several times (one tap for each burr) (Summers 1994; Zitzmann & Scharer 1998; Rosen et al. 1999; Nkenke et al. 2002b) to one or none, as the probability of a membrane perforation increases with every single sinus floor tap. In the best case, the kernel breaking via the root elevator is accompanied by an insignificant bone displacement, which is compensated by the elasticity of the Schneiderian membrane.

A further essential factor is the detachment and elevation of the Schneiderian membrane from the sinus floor. The detachment of the Schneiderian membrane is the most delicate manipulation in the SFE. Initially, this was made with the osteotome, inserting it to the desired depth. The elevation of the membrane can be performed either with the osteotome or the implant (Hahn & Babbush 2001) or via a bone substitute (Zitzmann & Scharer 1998) or blunt elevator (Nkenke et al. 2002b). Using hard objects (osteotomes, implants, substitute) causes a point overloading, which frequently leads to perforation. It has been proposed that the surgeon could take advantage of hydraulic forces created during the osteotome SFE to avoid rupture of the sinus membrane (Summers 1994; Rosen et al. 1999). However, this idea has never been tested either in experimental or in clinical studies. We used the osteotome to cause hydraulic pressure with the blood to achieve a very gentle detachment of the Schneiderian membrane. The osteotome acted as a piston because of the exact socket wall preparation, the blood from the socket walls served both as a seal as well as hydraulic medium, and the Schneiderian membrane as a valve. The osteotome was used afterwards to push the substitute materials to the top of the implant socket, and the blood pumped into the socket served as a cushion to prevent the substitute materials from being directly pressed against the membrane.

The use of bovine bone substitute material Bio-Oss® plus blood only leads to a very limited new bone formation (Yildirim et al. 2000; Yildirim et al. 2001; Stavropoulos et al. 2003) in SFE. Thus, Bio-Oss® may be denoted as osteocompatible rather than osteoconductive (Stavropoulos et al. 2003). It has been suggested that a mixture of 80% bovine hydroxyapatite and 20% autogenous bone should enable a predictable bone augmentation (Wallace et al. 1996; Hallman et al. 2001). However, to achieve highly predictable bone augmentation in SFE, autogenous bone graft is needed (Cordaro 2003; Merkx et al. 2003; Pinholt 2003). As in minor SFE, only a small bone quantity is needed; the use of trephine burr instead of a series of burrs enables the achievement of a bony kernel for the augmentation purpose. The major advantage of a graft from the implant socket is that a donor site is not needed, as Bio-Oss® seems to be resistant to resorption, which may lead to an increased bone density compared with that of adjacent native bone (Schlegel & Donath 1998). Moreover, since it is known that implant failure is more common in bone of low density than in denser bone qualities (Friberg et al. 1991; Jaffin & Berman 1991), the use of Bio-Oss® may also be advantageous from this point of view. In addition, slowly resorbable deproteinised bone particles contribute to stable augmentation of the maxillary sinus floor by inhibiting bone resorption (Xu et al. 2004). Thus, we used a mixture of Bio-Oss® and 50% autogenous bone to prevent resorption of the autogenous graft, and to achieve dense bone quality and sufficient substitution volume.

Compared with the survival rate of 88% reported by Nkenke et al. (2002b), who used a modified routine as introduced by Summers (1994) and endoscopical control for minor SFE, Rosen et al. (1999) reported a survival rate of 96%. We achieved a survival rate of 100% with the technique presented here. However, stronger restrictions regarding the minimum residual height of the alveolar crest (6 mm) than those used by Nkenke et al. (2002b) or 4 mm and 5 mm by Rosen et al. (1999) further limit the application of the presented method. Six millimetres as a minimum of residual crestal height for a safe implantation was also suggested by Zitzmann & Scharer (1998). Furthermore, high predictability of the described method can be expected only in SLA®-ITI® implants with diameter of 4.8 mm or in implants with the same surface properties (Li et al. 2002) and dimensions. Anatomically, the method is restricted to the restitution of the first upper molars if the second molars are present to prevent the bone reduction at this site, and also to the restitution of the second molars, because of the larger alveolar crest of the tuber maxillae.

Conclusions

The presented procedure for minor SFE offers harvesting of autogenous graft from the implant socket and a precisely prepared implant socket, and hence providing reliable implant anchoring. In addition, this technique replaces the risky instrumental detachment of the membrane by the safer hydraulic detachment and gradual elevation. Thus, the described method, despite its restrictions, is highly predictable, and does not need special equipment. It lowers the morbidity, shortens the surgery duration, and as a consequence reduces the patient's costs. Prosthodontic treatment is possible after a relatively short period of 3 months. The extremely low morbidity and the reduced patient costs are important in increasing the patients' acceptance.

Acknowledgements: We thank Mrs Adelina Vitkov for the image acquisition and Mr Andreas Zankl for the graphic drawing and image processing.

Résumé

Un épaississement mineur du plancher sinusal est une méthode ayant une prévision relativement élevée mais qui est techniquement exigeante. Une amélioration de la technique et une augmentation de la prévision sont donc souhaitables. Un protocole clinique pour l'épaississement mineur du plancher sinusal avec des implants SLA®-ITI® (implants mordançés, soufflés avec de larges particules et d'un diamètre de 4,8 mm) est décrit. L'usage des trépans à la place de fraises spirales rendait possible la collecte de greffons autogènes de l'alvéole de l'implant et garantissait une alvéole implantaire parfaite. Cette dernière est nécessaire pour un ancrage implantaire optimal et pour le scellement hydraulique entre l'alvéole et l'ostéotome. Le trou permet un détachement hydraulique de la membrane de Schneiderian, où le coussin sanguin se détache graduellement et élève la membrane prévenant son contact avec le greffon. Huit patients ont été traités avec succès par cette méthode. Aucune perforation membranaire n'est apparue et la guérison s'est effectuée de la bonne manière chez tous les patients. Tous les implants ont été mis en charge trois mois après leur insertion. Le protocole clinique

présenté procure une prévision importante dans l'aspect clinique, une très faible morbidité et un temps chirurgical raccourci.

Zusammenfassung

Die Anhebung des Sinusbodens mittels hydraulischer Ablösung und Elevation der Schneider'schen Membran

Ziele: Die Elevation des Sinusbodens im kleinen Rahmen stellt eine Methode mit einer relativ hohen Voraussagbarkeit dar, ist aber technisch anspruchsvoll. Eine Verbesserung der Technik und eine Steigerung der Voraussagbarkeit wären wünschenswert.
Material und Methoden: Es wird ein klinisches Protokoll zur Elevation des Sinusbodens im kleinen Rahmen mit SLA®-ITI® Implantaten (grobkörnig säuregeätzte Implantaten mit einem Durchmesser von 4.8 mm) beschrieben. Die Verwendung von Hohlfräsen anstelle von Spiralbohrern ermöglicht die Gewinnung von autologen Knochentransplantaten aus dem Implantatstollen und garantiert ein perfektes Implantatbett. Das letztere ist notwendig für eine optimale Implantatverankerung und für das hydraulische Siegel zwischen dem Implantatbett und dem Osteotom. Das Ganze erlaubt eine hydraulische Ablösung der Schneider'schen Membran, indem das Blutkissen nach und nach die Membran ablöst und anhebt und den Kontakt mit dem Transplantat verhindert.
Resultate: Acht Patienten wurden erfolgreich mit der oben beschriebenen Methode behandelt. Es traten keine Perforationen der Membran auf und bei allen Patienten verlief die Heilung komplikationslos. Alle Implantate konnten 3 Monate nach Platzierung prothetisch versorgt werden.
Schlussfolgerungen: Das vorgestellte klinische Protokoll liefert eine hohe Voraussagbarkeit der klinischen Resultate zusammen mit einer extrem niedrigen Morbidität und verkürzten chirurgischen Eingriffen.

Resumen

Objetivos: La elevación menor del seno es un método con un relativamente alta predictibilidad pero es técnicamente exigente. Es deseable una mejora de la técnica y un aumento de la predictibilidad.
Material y métodos: Se describe un protocolo clínico pata elevación menor del seno con SLA®-ITI® (implantes de granulado grande y gravado ácido con diámetro de 4.8 mm). El uso de trépano en lugar de fresas espirales permite la recolección de injertos autógenos desde el orificio del implante y garantiza un orificio implantario perfecto. Esto último es necesario para el anclaje óptimo del implante y para el sellado hidráulico entre el orificio y la osteotomía. Todo ello permite una separación hidráulica de la membrana de Schneider, donde el colchón sanguíneo se separa gradualmente y eleva la membrana, previniendo su contacto con el injerto.
Resultados: Se trataron con éxito ocho pacientes con el método descrito anteriormente. No hubo perforación de la membrana y se observó una cicatrización sin incidentes en todos los pacientes. Todos los implantes se cargaron prostodonticamente a los 3 meses de la implantación.
Conclusiones: El protocolo clínico presentado suministra una alta predictibilidad en los resultados clínicos, junto con una extremadamente baja morbilidad y una cirugía acortada.

要旨
目的：小規模な上顎洞挙上術は比較的予知性が高いが技術的には難しいので、術式の改善と予知性の向上が望まれる。
材料と方法：SLA®-ITI®（大きい粒径のグリットと酸エッチングを施した直径４．８ｍｍのインプラント）を用いた上顎洞底挙上術の臨床的プロトコールを述べる。スパイラル・バーの代わりにトレファンを使用すれば、骨床から自家骨移植片を採取することができ、完璧なインプラント床を確保できるが、これはインプラントの最適な固定と骨床とオステオトーム間の水圧による封鎖を得るために不可欠である。その結果、シュナイデル膜の水圧による剥離が可能となり、局所では血液が徐々に膜を剥離し、挙上してゆき、膜と移植骨の接触が妨げられる。
結果：上記の術式によって患者８名を成功裏に治療した。膜の穿孔例はなく、全ての患者は問題なく治癒した。全てのインプラントは、埋入後３ヵ月後に補綴物を装着して荷重した。
結論：本臨床的プロトコールは予知性の高い臨床的結果と、極めて低い合併症率および手術時間の短縮をもたらした。

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