Placement of Posterior Maxillary Implants in Partially Edentulous Patients with Severe Bone Deficiency Using CAD/CAM Guidance to Avoid Sinus Grafting: A Clinical Report of Procedure

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Purpose: *To provide a detailed presentation of computer-aided design/computer-assisted manufacture guidance in severely resorbed posterior maxillae to place implants in a very limited amount of bone, thus avoiding sinus grafting.* ***Materials and Methods:*** *Based on computerized tomography (CT) axial images, implant positions are planned using imaging software. A surgical template is fabricated and drilled with a numerically controlled machine to transfer the planned positions to bone with high accuracy. To avoid sinus grafting, implants can be planned in the anterior or posterior wall and in the septa of the sinus as well as in the palatal curvature. Recipient site preparation is done transgingivally with a drill or with a dedicated bone spreader to increase the amount of bone when necessary.* ***Results:*** *Fifteen resorbed posterior maxillae were treated with a fixed prosthesis supported by a combination of 42 upright and tilted implants. In all cases, implants were placed as planned. Seventeen implants were tilted at a 20- to 35-degree angle with the line perpendicular to the axial CT images. Seven implants were placed in the palatal curvature, 11 implants were close to the anterior wall, and two of them in combination with the palatal curvature. Only one implant was placed close to the posterior wall and two were placed in septa. All patients attended scheduled follow-up visits. During the 4-year observation period, no complications were recorded, no implants were lost, and there was no infection or inflammation.* ***Conclusion:*** *This proof-of-concept study suggests that the use of an image-guided system associated with bone spreading for oral implant placement in the atrophic posterior maxilla can be an alternative to sinus grafting.* INT J ORAL MAXILLOFAC IMPLANTS 2009;24:96–102

Key words: *atrophic maxilla, bone graft, bone spreading, computer-aided surgery, implant dentistry, maxillary sinus, minimally invasive surgery, surgical flap, tilted implants, x-ray computerized tomography*

In the severely resorbed posterior maxilla, implant placement posterior to the first premolar requires bone grafting, a well-documented procedure in the literature.[1,2] Following the creation of a window in the buccal side of the sinus, the schneiderian membrane is elevated prior to the placement of bone to increase the volume of bone. Implant placement is delayed. The drawbacks of sinus lifting are increases in treatment duration and cost, the choice of a donor site, possible surgical complications at the donor and host sites, and patient acceptance. To overcome these negative aspects, some have suggested using alternative anatomic features to place the implant, such as the anterior or posterior wall and the septa of the sinus, the palatal curvature, and the pterygoid process.[3,4] Although this approach seems to be simpler, it requires a high level of skill and can become invasive if the sinus border is perforated to introduce a straight probe to determine the inclination of the anterior and posterior parts of the sinus wall.

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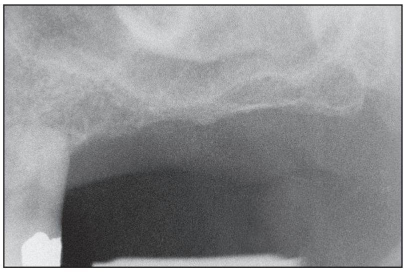


Fig 1a A Subantral Option 4 (SA-4) sinus according to the intraoral radiograph.

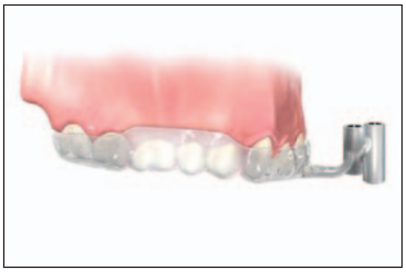


Fig 1b For the CT exam, the diagnostic prosthesis was duplicated in acrylic resin and then used as a scanning template. The acrylic resin teeth were made radiopaque so that they would be clearly visible on the radiograph. A cube was fixed at the front of the template so that it was outside the patient's mouth, in front of the maxilla of interest for the scanning procedure.

In the past decade, image-guided systems (IGSs) have been suggested for blind surgery to reduce the invasiveness of the surgical procedure.[5,6] Whatever the technology used (navigation or template), the objectives of IGS are twofold: defining an operative strategy that takes advantage of the localizing capabilities of imaging, and performing the previously defined operative procedure using a less invasive protocol with a suitable guidance system. Several authors have demonstrated the capability of IGS to place oral implants in bone with high accuracy.[7]

The objective of this paper is to detail the use of an IGS in severely resorbed posterior maxillae as a new option to place implants in a very limited amount of bone in the aforementioned anatomic features.

MATERIALS AND METHODS

Patients were treated by one of the three surgeons involved in the study. All surgeons had experience in oral implant placement and were well trained with the IGS used.

In late 2003 and early 2004, during a 6-month period, every patient who presented for the placement of implants in the posterior maxilla was eligible for inclusion in this case series. This was performed within the guidelines of the Helsinki declaration. Patients were informed of the procedure and provided written, informed consent. Inclusion criteria were as follows: the need for bone grafting from the lateral side of the sinus (Fig 1a), refusal of the conventional sinus lift procedure, implant placement required to support a prosthesis, and age over 18 years. Exclusion criteria were as follows: the need for tooth extraction during the surgical procedure, pregnancy at the time of evaluation, metabolic disorders, immunocompromised status, hemophilia or other bleeding disorders, drug or alcohol abuse, treatment with steroids, history of radiation therapy in the head and neck, psychiatric disorders, and inability to understand the procedure described.

Planning Procedure

Primary planning was based on intraoral findings and standard radiography, intraoral radiography, and the orthopantomogram. When the treatment option decided by the dental surgeon was sinus elevation with creation of a window in the lateral antral wall, the patient was informed of the possibility of receiving the alternative treatment involving image guidance, tilted implants, and bone spreading. In the planning stage, following a complete examination of the patient, the restorative clinician created a study prosthesis on diagnostic casts that represents the final restorative prosthesis. After satisfactory testing in the patient's mouth, the study prosthesis was duplicated in acrylic resin and then served as a scanning template. Teeth were fabricated in radiopaque acrylic resin.

Typically, an IGS for oral implant placement consists of a software program for virtual implant placement and a suitable guidance system to carry out the predefined operative strategy. In the EasyGuide protocol (Keystone-Dental, Burlington, MA), a scanning template is used to transfer the planned implant to the surgical site. Prior to surgery, the template is drilled with a numerically controlled drilling machine according to the preoperative plan made with imaging software. The link between the software and the drilling machine is an acrylic resin cube that is a fiducial marker provided with the imaging software that includes two precisely positioned tubes made of titanium. For the scanning procedure, the cube is fixed to the previously fabricated scanning template so that it is outside the patient's mouth, in front of the maxilla (Fig 1b). The template is supported by residual teeth.

Axial images are obtained from a fan-beam spiral computerized tomography (CT) scan or a cone-beam CT scan. They are transferred to the EasyGuide planning software. For each patient, the practitioner had to define the positions of the implants with the software according to the diagnostic radiopaque acrylic resin teeth included on the scanning template

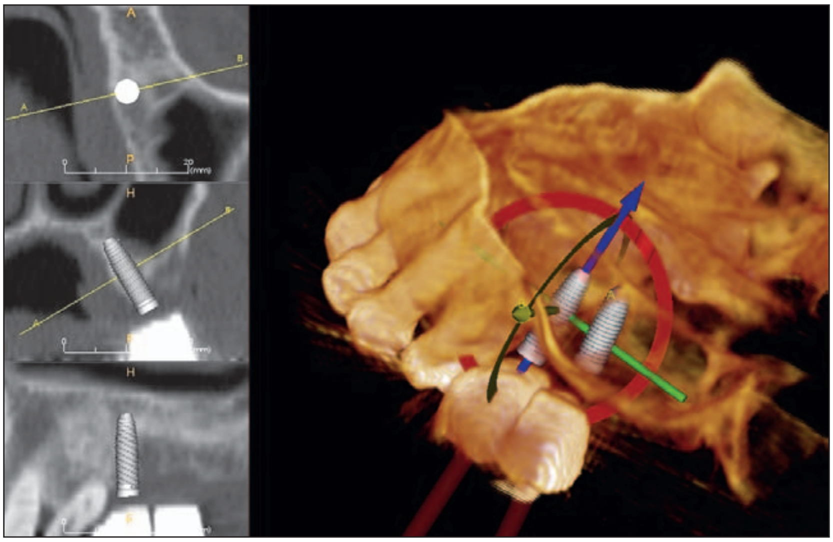


Fig 2 The EasyGuide planning software is used for three-dimensional planning. Reformatted views always pass through the planned implant axis. The practitioner can interactively change the position of the planned implant in each plane until the result is satisfactory. The simulation is carried out in real time in all three planes.

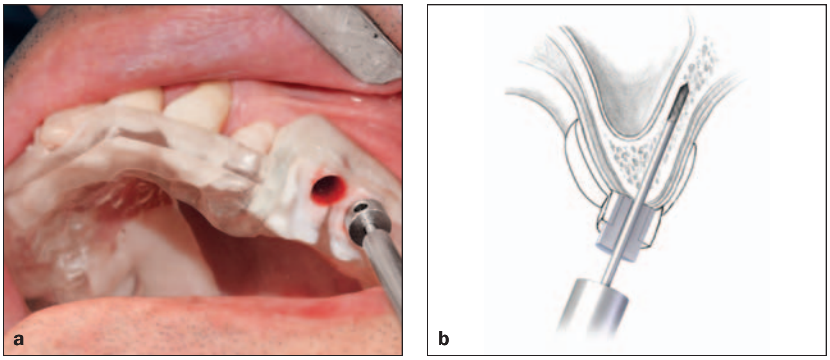
Fig 3a The scanning template is drilled with high accuracy according to the plan and then becomes a surgical guide. Note that the implant axis corresponds to that of the planned teeth. For the surgical step, the X fiducial marker has been removed.

Fig 3b The plaster is also drilled. The plan is physically assessed before surgery and can be modified if necessary.

and the available bone volume (Fig 2). In the severely resorbed posterior maxilla, the amount of bone is limited; consequently, the implant position represents a compromise between the ideal axial prosthetic position and the bone volume. For each patient, implants were planned according to the prosthetic plan. The implants were planned upright at all points where the CT scan demonstrated sufficient bone volume. Otherwise, the practitioner attempted to find a bone recipient site close to and parallel to the anterior or posterior sinus wall, or in the palatal curvature or a septum. In addition, the practitioner had to take care that the tilted axes intersected the planned teeth so that implant placement was both bone- and prosthesis-driven, rather than merely bone-driven.

Surgical Procedure

Prior to surgery, the drilling machine makes holes on the template and on the plaster cast. The plan can be physically checked at this stage, on both the template and on the plaster cast, and modified if the implant position would risk a prosthetic failure (Figs 3a and 3b). After appropriate anesthesia is obtained, the drilled template is placed in the mouth and fitted onto the mucosa, in the same position as during the CT examination. For partially edentulous patients in this study, the template was immobilized by the remaining teeth to prevent inadvertent movement of the surgical guide during initial osteotomy. Drill sleeves are inserted into the template holes. First, a 2-mm drill is passed through the drill sleeve to create a concavity at the top of the crest. This first drill sleeve is removed and replaced with another drill sleeve, 1.6 mm in inner diameter. A bone spreader (ie, a straight probe) is then inserted and passed through the oral mucosa and the bone to create the pilot hole to the desired depth (Fig 4). The template is then removed. A small incision is made at the top of the crest to visualize the entrance of the pilot hole. Tapered bone-spreading screws are then inserted into this first hole to enlarge the osteotomy. Several tapered bone spreaders of increasing diameter are used until the implant diameter is reached (Fig 5). After each spreader, the practitioner introduces a straight probe into the hole to

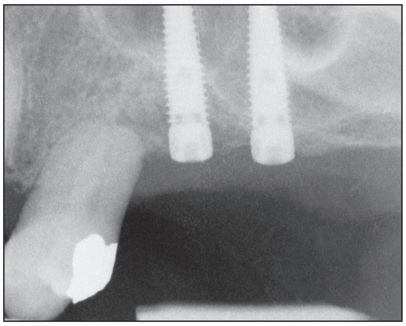


Figs 4a and 4b The template is placed in the mouth in the same position as during the CT examination. The template is fitted on the mucosa. Drill sleeves are inserted through the holes *(a)*. The first surgical tool passed through the sleeve is a bone spreader, used to carry out the pilot bone expansion *(b)*.

Fig 5 A small incision is made at the top of the crest to visualize the pilot preparation. Bone enlargement is continued by passing tapered, screw-type spreaders of increasing diameter until the planned implant diameter is reached.

Fig 6 *(left)* Tapered implant in place in bone at the recommended length.

Fig 7 *(right)* Definitive prosthetic result.



assess the integrity of the bone cavity. If no bone perforation is detected, a tapered implant is placed into the bone (Fig 6). The definitive prosthesis is made 4 months later (Fig 7).

RESULTS

This paper reports on 11 consecutive patients (seven women and four men with ages ranging from 44 to 75 years) who presented for the placement of implants in the Department of Oral Surgery of the Hospices Civils de Lyon with a follow-up period of 4 years. Fifteen resorbed posterior maxillae were treated with a total of 42 implants ranging in length from 8 to 13 mm and in diameter from 3.5 to 5.0 mm. In all cases, implants were placed at the planned locations and with the desired dimensions. No bone perforations were highlighted by the practitioners. Seventeen implants were planned in a tilted configuration, with an angle with the perpendicular line to the axial CT images ranging from 16 to 35 degrees. Seven implants were placed in the palatal curvature, 11 implants were close to the anterior wall, and two were placed in combination with the palatal curvature (Table 1). Only one implant was placed close to the posterior wall, in combination with the palatal curvature, and two were placed in a septum. Every implant was placed with a primary stability of 35 N/cm. One implant was lost before loading. The lost implant was planned with the apical third in the antral lumina. This implant was placed in the remaining bone and the antral space with a simultaneous crestal augmentation procedure using an osteotome passed through the residual crest. This event was not related to the technique detailed in this paper.

Healing in all cases was uneventful, as expected. Five subantral spaces were completely restored with a fixed prosthesis, and in 10 patients the second molar was not replaced (Table 2). None of the patients withdrew from the study. All patients attended the scheduled follow-up visits. During the 4-year observation period, no complications were recorded, no implants were lost after loading, and there was no infection or inflammation.

Table 1 Characteristics of Recipient Sites Prepared with Bone Spreader

Location	No. of sites	Inclination (range, deg)	Implant length (range, mm)	Implant diameter (range, mm)
Palatal curvature	4	17–31	10 to 12	4.0
Anterior wall	9	16–30	10 to 13	3.5 to 5.0
Septa	2	0 and 15	8.0 and 10	3.5 and 4.0
Palatal curvature and anterior wall	2	30 and 35	10 and 12	3.5
Palatal curvature and posterior wall	1	35	13	4.3

Table 2 Locations and Numbers of Implants Placed

Missing teeth	No. of patients	No. of patients with all teeth replaced	Teeth not replaced in partially edentulous patients
First and second molars	1	1	–
Second premolar, first and second molars	2	1	Second molar
Two premolars and two molars	5	2	Second molars and (in one case) the first molar as well
Canine, premolars, and two molars	7	1	Second molars and (in two cases) the first molar as well

DISCUSSION

This case series demonstrates that implant placement in a severely resorbed sinus region need not always entail bone grafting. Instead, IGS can be used to place implants in a very limited amount of bone. The advantages of this surgical method as a therapeutic option are clear: it reduces surgical and treatment duration by eliminating the graft healing period, thereby reducing the cost of treatment; it reduces patient and practitioner discomfort and the risk of morbidity; and it should increase patient acceptance, particularly for those with a severely resorbed posterior maxilla if the only other option is to harvest bone from the iliac crest under general anesthesia.

The use of the aforementioned anatomic features, except for septa, has already been described.[3,4] Implants placed close to the anterior or posterior sinus wall, tangential to the palatal curvature, can be expected to provide acceptable support for fixed prostheses. This paper presents software to accurately analyze the three-dimensional (3D) bone volume, evaluate the amount of bone in any direction, and assist in fabrication of a numerically drilled template that provides firm guidance during the implant placement process. This technique takes advantage of a limited amount of bone and reduces the invasiveness of the surgical procedure. It is not necessary to raise a flap or to introduce a straight probe into the sinus to visualize the sinus wall.[3] Without the use of IGS, tilted implants would have to be placed subsequent to a visual localization of the sinus wall or the palatal curvature, which requires additional surgical skill. Furthermore, IGS allows the surgeon to take advantage of septa, an option that is not routinely described with conventional procedures. Septa are often intact: 31.7% of sinus floors had at least one septum according to Ulm and coworkers,[8] with most septa located in the region between the first and second premolars with a mean height of 7 mm. With IGS, septa are no longer considered as a possible complication[8] but rather as an advantage.

The technique presented in this paper uses a bone spreader instead of a conventional drill set. Indeed, in previous studies describing the use of the aforementioned anatomic structures, implants are placed in recipient sites that offer a bone volume that is greater than the implant size. In this case series, the bone ridge was sometimes narrower than the planned implant diameter. The use of bone spreaders is mandatory with a limited amount of bone, in the palatal curvatures or septa; it is also required when the implant has to be placed as close as possible to the sinus wall so that there is ideal posterior support for a prosthesis. Bone spreaders were able to spread the bone, permitting implant placement in thin crests, whereas drills would have destroyed the bone. Preservation of the external periosteum also helps preserve vascularization of the osseous sinus floor or bony crest, which may contribute to the success of osseointegration. It remains to be determined (*1*) whether the spreaders spread the bone or condense the bone, and (*2*) the minimal amount of bone required to place an implant. Further investigations are necessary to answer these questions.

Another question remains: is the implant covered by bone completely after insertion? An investigation of the predictability of the system used,[5] the prosthetic outcome of this case series with 4 years of follow-up, the primary stability quoted as 35 Ncm, and practitioner assessments of the recipient sites seem to answer that question affirmatively. However, an in vivo study[9] of image-guided implant placement using a template of different technology found errors of 2.99 ± 1.77 mm at the implant apex. Those placement errors are not compatible with the procedure described in that paper. Therefore, and despite the positive results of the present case series, further investigations should provide postoperative CT scans to confirm the accuracy of the system used with quantitative data. However, this procedure was not allowed by the ethical board at the time of this study.

With the procedure proposed in this paper, implants are often tilted. This does not seem to be a drawback since preliminary studies of fixed prostheses supported by a combination of upright and tilted implants have indicated high survival rates.[3,4] The tilted implant, which employs the anatomic features of the arch, has the advantage of expanding the prosthetic base of the arch. Despite the advantages of this procedure from a surgical standpoint, there is a technical aspect that should be analyzed: in this case series, the second molar was not replaced in 10 patients. This does not seem to be a problem for the rehabilitation of the completely edentulous maxilla,[10,11] since a bilateral cantilever is an acceptable option. But, for a partially edentulous patient, it might be asked: (*1*) Is the replacement always necessary for biomechanical reasons?[12] (*2*) Is a distal cantilever an acceptable option?

Within the limited number of observations in the present cases series, this study confirms that 3D analysis outperforms the results seen with a conventional planning procedure.[13] Indeed, the standard imaging technique cannot provide information on the 3D structures of the jawbone. The standard technique—intraoral and panoramic radiography—is subject to image distortion, superimposition, or overlapping. CT provides easy data transformation for use in 3D analyses, software, and transfer technology. To reduce radiation exposure, the use of cone-beam CT[14–16] has been suggested.[17]

This case series demonstrates that in severely resorbed posterior maxillae, when treatment based on standard radiography may consist of sinus grafting with creation of a lateral window, the use of CT images and dedicated planning software may make it possible to avoid grafting. Therefore, a CT exam and IGS should become the method of choice for these clinical situations, provided that further studies confirm the clinical success expected, particularly regarding the survival rate, esthetic outcome, and the minimal amount of bone that can be used for expansion.

CONCLUSION

Within the limitations of this case series, encouraging results in favor of the use of an image-guided system for oral implant placement in the atrophic posterior maxilla were obtained. This surgical method reduces the duration of surgery and treatment by eliminating the graft healing period, thus reducing the cost of treatment, patient and practitioner discomfort, and risks of morbidity. It should also increase patient acceptance, particularly if donor bone would otherwise have to be harvested from the iliac crest under general anesthesia.

REFERENCES

1. Boyne P, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Maxillofac Surg 1980;38:113–116.
2. Wood RM, Moore DL. Grafting of the maxillary sinus with intraorally harvested autogenous bone prior to implant placement. Int J Oral Maxillofac Implants 1988;3:149–214.
3. Krekmanov L. Placement of posterior mandibular and maxillary implants in patients with severe bone deficiency: A clinical report of procedure. Int J Oral Maxillofac Implants 2000;15:722–730.
4. Calandriello R, Tomatis M. Simplified treatment of the atrophic posterior maxilla via immediate/early function and tilted implants: A prospective 1-year clinical study. Clin Implant Dent Relat Res 2005;7(supp1):S1–S12.

5. Fortin T, Bosson JL, Coudert JL, Isidori M. Reliability of preoperative planning of an image-guided system for oral implant placement based on three-dimensional images: An in vivo study. Int J Oral Maxillofac Implants 2003;18:886–893.
6. Fortin T, Bosson JL, Isidori M, Blanchet E. Effect of flapless surgery on pain experienced in implant placement using an image-guided system. Int J Oral Maxillofac Implants 2006;21:298–304.
7. Widmann G, Bale RJ. Accuracy in computer-aided implant surgery: A review. Int J Oral Maxillofac Implants 2006;21:305–313.
8. Ulm CW, Solar P, Krennmair G, Matejka M, Watzek G. Incidence and suggested management of septa in sinus-lift procedures. Int J Oral Maxillofac Implants 1995;10:462–465.
9. Di Giacomo GA, Cury PR, de Araujo NS, Sendyk WR, Sendyk CL. Clinical application of stereolithographic surgical guide for implant placement: Preliminary results. J Periodontol 2005;76:503–507.
10. Capelli M, Zuffetti F, Del Fabro M, Testori T. Immediate rehabilitation of the completely edentulous jaw with fixed prostheses supported by either upright or tilted implants: A multicenter clinical study. Int J Oral Maxillofac Implants 2007;22:639–644.
11. Rangert B, Jemt T, Jörnéus L. Forces and moments on Brånemark implants. Int J Oral Maxillofac Implants 1989;4:241–247.
12. Kayser AF. Shortened dental arch: A therapeutic concept in reduced dentitions and certain high-risk groups. Int J Periodontics Restorative Dent 1989;9:426–444.
13. Jacobs R, Adriansens A, Naert I, Quirynen M, Hermans R, van Steenberghe D. Predictability of reformatted computed tomography for pre-operative planning of endosseous implants. Dentomaxillofac Radiol 1999;28:37–41.
14. Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos Plus DS panoramic unit. Dentomaxillofac Radiol 2003;32:229–234.
15. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol 1999;28:245–248.
16. Mozzo P, Procacci C, Tacconi A, et al. A new volumetric CT machine for dental imaging based on the cone-beam technique: Preliminary results. Eur Radiol 1998;8:1558–1564.
17. Fortin T, Champleboux G, Bianchi S, Buatois H, Coudert JL. Precision of transfer of preoperative planning for oral implants based on cone-beam CT-scan images through a robotic drilling machine: An in vitro study. Clin Oral Implants Res 2002;13:651–656.