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Combination of straight and tilted implants for supporting screw-retained dental prostheses in atrophic posterior maxillae: A 2-year prospective study

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ABSTRACT

Objectives: To evaluate the two-year survival rate (SR) and marginal bone loss (MBL) of fixed dental prostheses (FDPs) supported by straight (S) and tilted (T) implants under the influence of diverse study variables.

Methods: A prospective investigation comprising 21 patients provided with a total of 27 maxillary screw-retained restorations fixed to 70 dental implants was developed. Two groups of implants were considered depending on their inclination with respect to the occlusal plane: Group 1 (S, $n = 37$): straight/axial implants and Group 2 (T, $n = 33$): tilted/angled fixations. Each FDP was supported by a combination of S and T implants. SR and MBL were assessed at the time of loading and two years after surgery. Patient-, surgical- and/or rehabilitation-related information was gathered. Data were statistically analysed at the $\alpha = 0.05$ significance level.

Results: After 24 months, a 100% SR was achieved and the MBL of S and T implants were statistically similar. T implants located in the molar region showed lower MBL than did those replacing premolars ($p = 0.031$).

Conclusions: Upright and angled fixations inserted at posterior maxillary areas resulted in comparable survival rates and peri-implant MBL after two years. The marginal bone resorption around tilted implants depended on their location.

Clinical significance: Screw-retained restorations fixed to straight and tilted implants seem to be a safe treatment option in posterior atrophic maxillae.

1. Introduction

Posterior tooth loss leads to a series of anatomical changes that create a significant obstacle to restoring free-end edentulous spaces of atrophic jaws [1]. As a result, the chewing ability, aesthetics and social relations of these partially edentate patients may be impaired [1–9].

According to the classification of Lekholm and Zarb [10], the bone quality types III and IV are the most common in the posterior maxilla. The functional occlusal forces are much higher in the molar region than in the anterior sectors [2]. Moreover, there is a significant lack of bone availability after tooth loss in this location due to both the pneumatisation of the maxillary sinus [2,11] and the centripetal and vertical bone resorption process [12], which results in unfavourable crown–implant ratios in the posterior maxillary zone as the maxilla is less dense than the mandible [2,12,13].

The literature has described numerous techniques attempting to circumvent the anatomical and physiological difficulties caused by tooth loss in the posterior maxilla [13–21]. Of these methods, the following are worth mentioning: cantilevered implant-supported fixed dental prostheses (FDPs) [16,17,21]; sinus lifting, using either a lateral window or an osteotome procedure with a crestal approach [14]; bone grafting [13]; osteodistraction [15]; short [19], pterygoid [18], or zygomatic implants [20,22] and, finally, the use of tilted implants [16,23–33].

Several authors have suggested the effectiveness of angled fixations (placed distally, either parallel to the anterior wall of the maxillary sinus or mesial to the mental foramen nerve) in avoiding vital structures and obtaining greater anchorage to the cortical bone [16,17,30]. The theory behind this philosophy is that a greater anterior–posterior position of the implant distributes the occlusal forces; therefore, the

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transverse force placed on the tilted implants is not detrimental to them. In the maxilla, the distal implants can also be benefitted from the cortical bone wall of the sinus and the nasal fossa [27,34].

However, even though this treatment has been proposed as a valid therapeutic alternative that may supply many surgical and prosthetic advantages [21], there is still insufficient evidence to support its widespread use for the restoration of posterior edentulous areas of atrophic jaws.

Hence, the aim of this paper is to assess the main clinical outcomes of tilted implants when combined with dental implants inserted axially to the occlusal forces in the partial rehabilitation of resorbed posterior maxillae two years after surgery.

The null hypotheses tested after two years of follow-up were that *a)* neither the implant survival rate (SR) nor the peri-implant marginal bone loss (MBL) are influenced by the implant inclination with respect to the occlusal plane (*i.e.,* straight or tilted) and that *b)* the MBL of tilted implants does not depend on patient-, surgical- and/or rehabilitation-related factors.

2. Materials and methods

2.1. Study protocol

2.1.1. Selection criteria and other related considerations

This two-year longitudinal prospective study was carried out at a private practice centre (Córdoba, Spain) with the collaboration of an university research team, who where experts in Oral Surgery (University of Seville, U.S., Spain) and Buccofacial Prostheses (Complutense University of Madrid, U.C.M., Spain).

The inclusion criteria were: *a)* partially edentulous patients aged 18 years or older, with at least 23 teeth, having missing teeth in the posterior maxilla, who were candidates for a screw-retained FDP fixed to a combination of straight and tilted implants; *b)* subjects presenting a level of bone atrophy (residual bone < 8 mm) under the maxillary sinus that would require either a bone graft to place straight implants or the insertion of tilted implants; *c)* patients with no medical contra-indications for oral surgical procedures (American Society of Anesthesiologists: ASA Class 1 or 2)[a]; *d)* subjects with full-mouth plaque scores and full-mouth bleeding scores of less than 25% at baseline; *e)* patients who understood the study and voluntarily signed an informed written consent to participate and *f)* subjects attending their clinical and radiographic follow-up appointments.

Patients were excluded based on any disease, condition, or medication that might compromise the osseointegration of the implants, such as: *a)* presence of active infection or swelling at the site of implant placement (in these cases, the infection was controlled prior to the surgery); *b)* presence of serious illness such as uncontrolled diabetes, autoimmune diseases, or severe blood-clotting problems; *c)* patients who had undergone radiation therapy in the head or neck in the past 12 months; *d)* patients to be restored with tilted implants both in the maxilla and the mandible (to avoid misinterpretation of the findings); *e)* pregnant women; *f)* inability or unwillingness to maintain a good level of oral hygiene; *g)* incapability or refusal to return for follow-up visits; *h)* cognitive impairment and/or *h)* motility disorders.

Patients meeting the selection criteria were invited to take part in this trial, which was developed between January of 2014 and December of 2016. All placed implants were somewhat angulated to the occlusal plane. However, this investigation took into consideration the definition of 'angled implant' proposed by Aparicio et al. [23]: *'an implant having an inclination greater than 15° in relation to the occlusal plane, whether in a mesio-distal, disto-mesial and/or bucco-palatal direction'.*

Two brands of dental implants were utilised: (a) Biomet 3i (Dental Ibérica, Barcelona, Spain) and (b) Nobel (Nobel Biocare AB, Göteborg, Sweden). Five models of Biomet 3i with slight differences in configuration were used: OSSEOTITE Parallel Walled; Full OSSEOTITE Parallel Walled; NanoTite Parallel Walled; OSSEOTITE Tapered and OSSEOTITE Parallel Walled Certain; while the Nobel implants were all NobelSpeedy Groovy RP. The best indicated implant type (according to their features and the patients' conditions) were selected in each case after the research team reached a consensus in a planning session.

This study was conducted in full accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki);[b] the Spanish Law 14/2007 for Biomedical Research;[c] and the Uniform Requirements for manuscripts submitted to Biomedical journals.[d] The approval of the Ethics Committee of the University of Seville (U.S., Spain) was obtained after the ethical board completed an independent review of the research protocol. The study was undertaken with the informed written consent of each participant. The privacy rights of the patients were always observed.

2.1.2. Surgical interventions

After applying local anaesthesia, the surgical area was prepared following the standard protocol for implant placement [35]. Thereafter, a slightly palatal mid-crestal incision was made, extending it into the gingival sulcus of the adjacent teeth and towards the tuberosity area. A full-thickness mucoperiosteal flap was reflected from the incision. The vestibular bone was exposed at the level of the maxillary sinus wall. Using the information from the radiological study, a lance drill was utilised to reach the maxillary sinus, whose anterior wall was explored with a Naber's probe. The most distal implant (T) was then inserted, following the anatomy of the aforementioned wall, with an angulation between 20° and 45° in relation to the occlusal plane and the implant platform was placed as distal as possible (Fig. 1). Subsequently, the straight implant (S) was inserted, and both fixations were evaluated for primary stability.

The surgical procedure was concluded by suturing the flap (Gore-Tex sutures, WL Gore & Associates Inc., Flagstaff, AZ, US). The healing period was monitored to ensure infection-free regeneration and soft tissue primary closure. Patients were prescribed twice-daily rinses with 10 ml of 0.12% chlorhexidine solution for 14 days and were reviewed weekly for a month.

2.1.3. Restorative procedures and second-stage surgery

Ten days after surgery, the sutures were removed and acrylic removable partial dentures (RPDs) with wrought-wire clasps were offered to our patients as temporary restorations. The decision to wear a provisional prosthesis during the osseointegration period (or not) was left in their hands.

The second surgery, performed 3 months later, consisted of

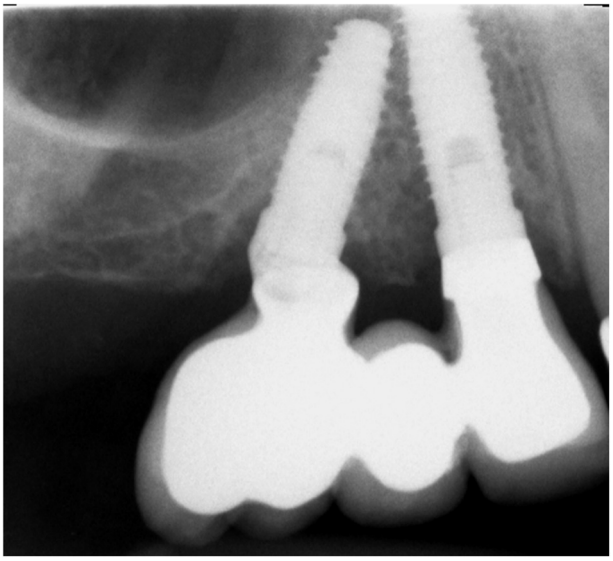

Fig. 1. Tilted implant placed parallel to the anterior maxillary sinus wall.