Retrospective Observational Study

TEN-YEAR IMPLANT SURVIVAL AFTER MAXILLARY SINUS LIFT WITH PIEZOELECTRIC SURGERY AND ILIAC CREST AUTOGRAFT

D. Viscardi[1,2*], Fa. Carini[1,2], M. Giordano[1,2], Fb. Carini[1,2], G. Porcaro[1,2]

[1]Department of Medicine and Surgery, University of Milano-Bicocca, Milan, Italy;
[2]Private practitioner, Monza, Italy

[*]*Correspondence to*:
Daniele Viscardi, DDS
Department of Medicine and Surgery,
University of Milano-Bicocca,
Piazza dell'Ateneo Nuovo 1,
20126, Milan, Italy
e-mail: danieleviscardi22@gmail.com

ABSTRACT

The introduction of surgical techniques based on the exploitation of ultrasonic vibrations has made it possible to obtain important innovations in all dental fields. The present study aims to evaluate implant survival ten years after definitive prosthetic rehabilitation on implants inserted in a second surgical stage compared to the maxillary sinus lift performed using piezosurgery technology and the application of a graft taken from the iliac crest. A total of 8 patients were selected, aged between 25-70 years, awaiting implant-prosthetic rehabilitation of the postero-superior sectors, but with anatomical conditions initially not favorable to implant insertion. The total number of implants inserted is 42, of which 20 support a screw-retained prosthesis and 22 support a cemented prosthesis. They underwent a 10-year evaluation, positioned in two surgical stages in the posterior sectors of the maxilla. Of the 42 implants inserted, 2 were lost during the osseointegration phase. Once removed and reinserted, they showed no sign of failure at the second 5-year follow-up. In the remaining 40 implants inserted, after 1 and 5 years, stable implant osseointegration occurred. At 10 years, only 2 more implants were lost. The ten-year implant survival percentage of implants inserted six months after maxillary sinus lift, performed using piezoelectric technology and insertion of autologous bone from the iliac crest, appears very valid and in line with that obtained from numerous reviews of the literature on large sinus lift.

KEYWORDS: *implantology, implant survival, iliac crest graft, maxillary sinus lift, piezoelectric surgery*

INTRODUCTION

Background

A sufficient alveolar bone volume must be present to obtain a good functional and aesthetic outcome of implant therapy (1). In the 1980s, the type of implant was chosen based on the quantity of residual bone (2).

Over the years, different methods of increasing bone volume in deficient sites have been described: osteo-induction, through the use of appropriate growth factors (3, 4); osteoconduction, through the use of a graft that functions as a scaffold for bone regrowth, distractive osteogenesis, i.e., the execution of a fracture through a surgical technique with newly formed bone in the gap (5), guided bone regeneration, in which spaces preserved by the application of membrane-

Received: 2 December 2024
Accepted: 07 January 2025

barriers let new bone formation (6-8), and revascularized bone grafts, i.e., the transfer of vital bone, equipped with its vascular pedicle, from a donor site to a recipient site (9).

Over the decades, new bone formation through the maxillary sinus lift technique for implant insertion has seen numerous improvements that have helped medicine achieve today's results. Molinetti can be considered a pioneer of paranasal sinus surgery who, in the second half of the 1600s, performed access to the malar region of the maxilla through an incision in the soft and hard tissues (10). Mikulicz conceived the approach to the maxillary sinus via the inferior nasal meatus in 1887. George William Caldwell 1893 proposed a combined surgical approach to the maxillary sinus by creating access to the sinus at the level of the canine fossa, capable of allowing extensive exploration and cleansing of the site. In 1900, sinus surgical techniques continuously evolved, resulting in a greater conservative attitude. Boyne and Kruger introduced the basis for the current vertical bone augmentation procedures of the lateral-posterior sectors of the maxilla: they demonstrated the ability of the sinus walls to induce new bone formation following the lifting of the sinus membrane alone (11).

Thanks to the discovery of the potential new bone formation starting from the maxillary sinus floor and osteo-inductive and osteo-conductive properties of graft materials, the foundations of all surgical techniques for maxillary sinus lift began to be laid.

In the early 1970s, Hilt Tatum used autogenous bone harvested from the ribs to produce adequate vertical height in the posterior region of the maxilla for implant placement. The following year, he developed a technique for lateral access to the maxillary sinus to lift the sinus membrane and simultaneously position the implants. At the same time, he introduced the use of osteotomes to create the implant site (12).

In 1980, Boyne was responsible for developing the first scientific work on the use of autologous bone grafts at the level of the maxillary sinus aimed at increasing bone thickness for implant purposes (13). Mish modified this technique by designing a bone window in the wall lateral of the maxillary sinus, which, once tipped upwards, created a new floor of the maxillary sinus.

In the 1990s, Summers developed a technique to elevate Schneider's membrane crestally, using specific osteotomes capable of compacting the bone of the implant site both laterally and apically (14-16).

Thanks to progress in biomaterials, these methods have increasingly predominated over time, leading to the establishment of two main surgical techniques. The first surgical technique, called "small maxillary sinus lift, " involves the elevation of Schneider's membrane via transalveolar access. The second technique, defined as "large maxillary sinus lift, " consists of lifting the sinus mucosa through access from the anterolateral wall of the maxillary sinus and inserting graft material.

Over the years, dental bone surgery has mainly used manual and mechanical instruments. Manual instruments offer good control when used to remove limited amounts of bone in poorly mineralized areas, while mechanical instruments are useful where bone density is greater. Introducing surgical techniques based on the exploitation of ultrasonic vibrations has made it possible to obtain important innovations in all dental fields.

The phenomenon of piezoelectricity, or the ability of a material to generate a potential difference when subjected to mechanical stimuli, was discovered in 1880 by the brothers Pierre and Jacques Curie. From this moment on, the therapeutic applications of piezoelectric technology began to have an important diffusion until, in 1953, Catuna experimented with its application on extracted teeth, starting numerous studies on the use of this method on mineralized tissues (17). Among these, Mararowe McFall analyzed the advantages and disadvantages of ultrasonic technology compared to traditional rotary technology (18, 19).

In 1975, Horton et al., carrying out experiments on dogs, described how the bone surface was smoother with rotary instruments compared to ultrasound, although bone regeneration was superior (20).

Twenty years later, in 1998, Torrella performed a maxillary sinus lift using ultrasound equipment, but Vercellotti was responsible for introducing ultrasonic instrumentation, also called "piezoelectric", into the dental field. In a clinical study, Vercellotti describes the execution of a ridge expansion, which cannot be performed except with piezoelectric instrumentation, given the extremely thin thickness of the edentulous ridge (21-24).

Rationale and objectives

The present study aims to evaluate implant survival ten years after definitive prosthetic rehabilitation on implants inserted in a second surgical stage compared to the large maxillary sinus lift performed using piezosurgery technology and the application of a graft taken from the iliac crest. The checks were performed via radiological examination and objective evaluation. Therefore, the absence of postoperative complications, the effective increase in the vertical dimension of the alveolar ridge, and the successful implant osseointegration are considered.

MATERIALS AND METHODS

Patient selection

Patients were selected to ensure maximum similarity of intervention. The inclusion criteria were:

- partial or total edentulism of the diatoric sectors;
- residual bone height of 5-8 mm (SA3) or < 5 mm;
- acceptance of an implant-prosthetic treatment;
- informed consent of the patient;
- age greater than 18 years.

The exclusion criteria were:

- insufficient oral hygiene: the presence of plaque and bleeding index greater than 25%;
- serious systemic pathologies that interfere with surgery;
- presence of periapical lesions or other anomalies affecting dental elements adjacent to the maxillary sinus;
- current acute sinusitis;
- benign or malignant lesions, as well as foreign bodies within the maxillary sinus;
- habit of smoking;
- alcohol or drug abuse;
- acute odontostomatological infections;
- SA 4 or 5;
- remote or recent radiotherapy at the level of the oro-maxillofacial area;
- recent chemotherapy;
- recent bisphosphonate therapy;
- state of pregnancy;
- uncontrolled diabetes.

Study design

For the development of the study, a total of 8 patients were selected, aged between 25 and 70 years, awaiting implant-prosthetic rehabilitation of the postero-superior sectors but with anatomical conditions initially not favorable to implant insertion. The total number of implants inserted is 42, of which 20 support a screw-retained prosthesis and 22 support a cemented prosthesis. They underwent a 10-year evaluation, positioned in two surgical stages in the posterior sectors of the maxilla. The maxillary sinus lift operations with lateral access and autologous graft harvesting from the iliac crest were performed at the San Gerardo Hospital in Monza. The study was performed retrospectively, subjecting patients to radiographic checks and physical examination 10 years after surgery. For the radiographic evaluation, digital ortho-panoramic radiographs at three post-operative moments were considered: radiographic control one, five, and ten years after applying the definitive prosthesis on the implants.

Different parameters were taken into consideration through orthopantomogram examinations:

- peri-implant bone height, including the autologous bone graft inserted into the subantral space and the alveolar bone itself. Therefore, a possible loss of bone height mesial and distal to the implant surface was evaluated. A peri-implant bone reduction of less than 1-1.5 mm in the first year after implant insertion and less than 0.2 mm in the following years is considered physiological (25). The implant height was taken as a reference to overcome the limits given to the distortion of orthopantomography, thus making the quantification of the lost bone more likely. Each implant is independently monitored for any bone loss for a more precise assessment of implant success or failure;
- peri-implant radiolucency, an indication of peri-implantitis (26);
- quantification of new bone formation following the insertion of autologous bone in the context of a major sinus lift. It is carried out by taking the implant-abutment junction and the most apical bone-implant contact inside the maxillary sinus as reference points. An absence of bone gain indicates therapeutic failure and can occur following extensive resorption by the autologous graft;
- The presence of a diffuse radiopacity within the sinus is indicative of ongoing sinusitis.

The manifestation of an infectious process affecting the maxillary sinuses, in the context of a sinus lift performed using an autologous graft, is indicative of a possible loss of continuity of the sinus membrane, with consequent penetration of the autologous material contaminated by intraoral bacteria, into the space antral. Another possible cause is the dislocation of the implant in the sinus antrum (27).

For objective evaluation in the immediate post-operative period and during subsequent follow-ups, attention is paid to several aspects:

- absence of spontaneous pain or under horizontal and vertical mechanical forces: pain is the first parameter considered to exclude a possible peri-implant infectious or incorrect distribution of prosthetic loads. Persistent pain may occur in conjunction with increased implant mobility, even before radiographic abnormalities are detectable. This symptom is indicative of implant failure. Clinically, the presence of pain is verified by the percussion of the implant;
- The absence of implant mobility is objectively verified by exercising horizontal and vertical forces on the fixture. An implant movement of less than 75 microns is considered physiological (28);
- signs of inflammation affecting the soft tissues around the implants: redness, swelling, on probing or spontaneous, pain on probing. These clinical manifestations lead to a diagnosis of mucositis. At the same time, the detection of ongoing peri-implantitis presupposes the involvement of the peri-implant hard tissues in the inflammatory process, with consequent loss of bone support. This last parameter is confirmed by radiological investigation and indicates implant failure. As a diagnostic aid for the detection of peri-implant inflammation, a periodontal probe is used, passed circumferentially around the implant. Thus, bleeding on probing, absent in healthy peri-implant conditions, the probing depth, considered pathological if greater than 5 mm, and the presence of suppuration around the implant are recorded (29);
- signs and symptoms of acute sinusitis with late onset in the postoperative period can lead to graft failure if not resolved with simple antibiotic therapy. The symptoms to which attention is paid are nasal congestion, pain, a sense of tension in the face, hyposmia, and purulent discharge from the nose. The patient may also report migraines, bad breath, dental pain, and fever (30).

On radiographic analysis, the presence of partial or total opacification of the sinus is visible. Once the pathology has been detected, the cause can be traced back to a perforation of the sinus membrane with displacement of graft material in the antral space, obstruction of the ostium following edema of the mucosa lining the sinus, bacterial contamination of the grafted bone inserted into the subantral space.

The surgical operations reported in the study were carried out using the piezosurgery system. This technology allows osteoplasty and osteotomy cuts limited to mineralized tissues, thanks to the action of ultrasonic micro-vibrations capable of preserving the integrity of soft tissues, vessels, and nerves.

Patient assessment

In the preoperative phase, the patient’s medical history was investigated to exclude pathologies or pharmacological therapies that represent a contraindication to surgery for major sinus lift and implant insertion. Once the listed inclusion and exclusion criteria had been evaluated, we proceeded with the oral clinical examination. Then, orthopantomography and Dentalscan CT scan were performed to define the morphology of the sinus and the edentulous ridges, as well as the intermaxillary space and the degree of atrophy.

A therapeutic plan was developed after obtaining informed consent from the patient, which envisages the removal of autologous bone from the anterior iliac crest and simultaneous elevation of the maxillary sinus in the first phase, while in the second phase, the insertion of the implant.

Surgical protocol

These procedures are performed on a supine patient, subjected to total anesthesia and nasotracheal intubation to obtain free access to the oropharynx. An incision is parallel to the iliac prominence and placed approximately 1.5 cm internally to avoid injury to the lateral femoral cutaneous nerve.

Remaining on a supra-periosteal plane, the iliac muscle is pulled medially and the gluteal muscle on the external side, after which four osteotomies are carried out, and the bone block between the anterior superior iliac spine and the iliac tubercle is removed (Fig. 1). The bone block is then fragmented and temporarily preserved in a liquid composed of a sterile physiological solution and the patient's blood, taken during the surgical operation (Fig. 2).

After completing the suturing of the muscular and the intra-dermal layers, we proceeded with the maxillary sinus lift. Once the vestibular and palatal plexus anesthesia has been carried out, the access flap is incised and detached, keeping the instrument well adhered to the bone plane to preserve the integrity of the periosteum.

Using piezoelectric instrumentation equipped with a diamond ball insert, we proceed with an osteotomy and the removal of the lateral access trapdoor to the sinus (Fig. 3). The Schneiderian membrane is then separated from the bone planes, using a non-cutting insert, first cranially, then mesially and distally, and only finally caudally. Once the sinus membrane has been elevated, the bone graft is inserted into the subantral space (Fig. 4, 5).

Closing the access window is carried out only in some cases by applying a portion of cortical bone taken from the iliac crest, modeled, and fixed with osteosynthesis plates. Given the invasive nature of the plaque removal operation, in some patients, it was decided to close the window by applying an absorbable membrane, while in others, simple fibrin glue was applied.

Implant insertion was performed once the graft had been integrated, six months after the maxillary sinus lift operation, after detaching a full-thickness flap on the lateral wall of the sinus (Fig. 6-9). Once inserted, the implants were submerged beneath the soft tissue for 6 months.

Once the period of implant osseointegration has passed, we proceed with the uncovering of the implant and the replacement of the cap screw with the healing screw, which, emerging from the gum, allows it to be modeled as an emergence profile. After waiting about a month for the peri-implant soft tissues to heal, healing screws were substituted with transfert, and an impression was taken.

In three patients, rehabilitation took place using the Toronto Bridge, a prosthesis fixed with screws on mesostructures, which were in turn connected to the body of the implants with screws. Prosthetically, the screw access holes are positioned on the occlusal surfaces of the posterior teeth and the palatal surfaces of the anterior teeth and then closed with composite resin.

In the present study, this type of prosthesis was screwed onto a variable number of 6-7 implants for each upper jaw. During the physical examination, the evaluation of the peri-implant soft tissues took place directly, thanks to the possibility of removing the prosthesis with the aid of a specific screwdriver. Thus, using instruments, such as the periodontal probe, to check probing depth and bleeding was possible.

On five patients, a cemented prosthesis was instead applied, in which the prosthesis is cemented onto the abutments, while the connection screws are used for fixing the abutment to the implant. For each upper jaw, this type of prosthesis was mounted on a number of implants ranging from 2 to 5.

Since cemented prostheses were not removed from implants, the post-operative implant evaluation was carried out exclusively through instrumental radiographic examinations, intra-oral examination of the visible peri-implant tissues, and the detection of painful symptoms.

In the period following implant placement and prosthetic restorations, each patient was recalled for check-ups, starting with the removal of the stitches one week after the operation. During each recall, the state of health of the soft tissues was checked, and the patient was motivated to maintain oral hygiene at home to prevent the accumulation of plaque and tartar, as well as implant failure. In both types of prosthetic rehabilitation, the space between the base of the prosthesis and the keratinized gum allowed adequate peri-implant hygiene.

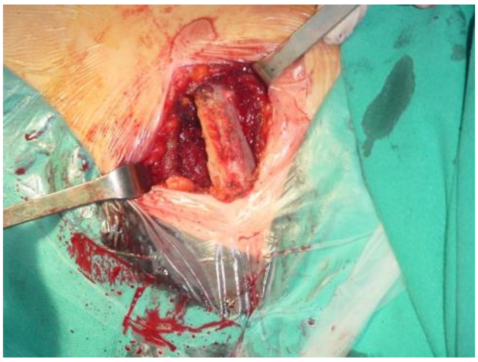

Fig. 1. *Autologous bone harvesting from the iliac crest: donor site.*

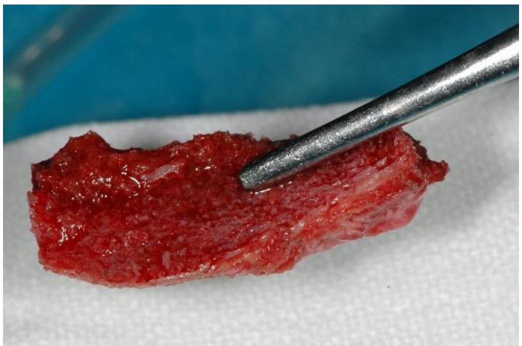

Fig. 2. *Piece of bone taken to be grafted.*

Fig. 3. *Maxillary sinus lift: bony trapdoor.*

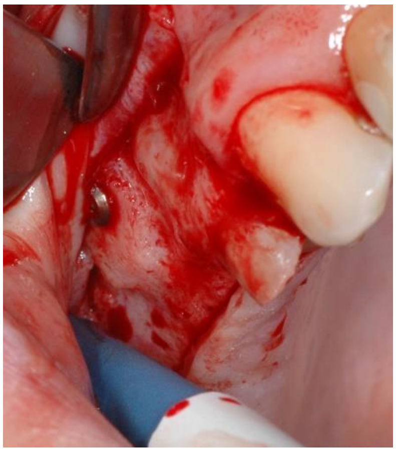

Fig. 4. *Onlay graft with fixation screws.*

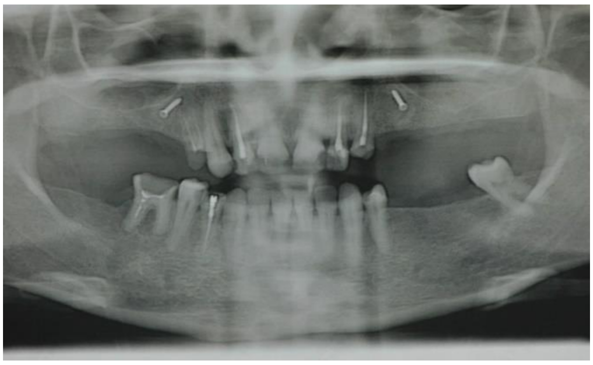

Fig. 5. *OPT was performed immediately after the iliac crest graft in the upper jaw.*

Fig. 6. *Insertion of 2 implants in the first quadrant.*

Fig. 7. *Insertion of 3 implants in the second quadrant.*

Fig. 8. *OPT was performed 6 months after the graft, at which time 2 implants were placed in the first quadrant and 3 implants in the second quadrant.*

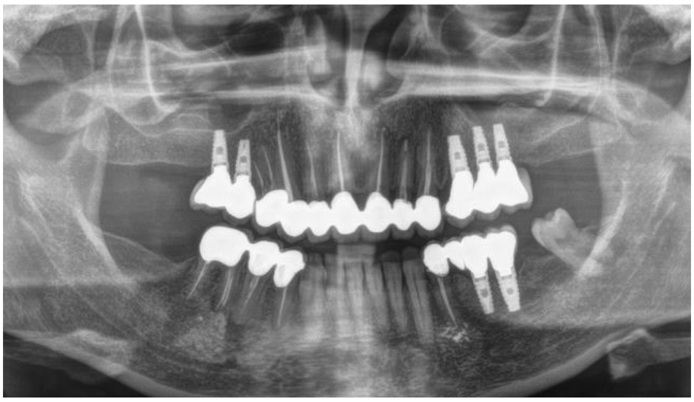

Fig. 9. *OPT performed at follow-up at 10 years, after checking the patient annually. The implants are still perfectly osseointegrated and loaded.*

RESULTS

Of the 42 implants inserted, 2 were lost during the osseointegration phase. Once removed and reinserted, they showed no sign of failure at the second 5-year follow-up. In the remaining 40 implants inserted, after 1 and 5 years, stable implant osseointegration occurred in the absence of early postoperative complications such as wound dehiscence, acute infection, perforation of the membrane due to the insertion of an excessive quantity of graft material, as well as late complications such as failure to integrate the graft, peri-implantitis, oro-sinus communication of chronic maxillary sinus infection. At 10 years, only 2 additional implants were lost. The surgical procedure of large maxillary sinus lift has made it possible to obtain prosthetic surgical success in patients with insufficient bone volume for implant insertion. The success obtained in this retrospective study was 95.2% at 1 and 10 years and 100% at 5 years (Table I).

Table I. *Prosthetic surgical success at 1, 5, and 10 years.*

Case	Age	Number of implants	Types of prosthesis	Implants lost 1 week after insertion	Implants lost 1 year after application of the definitive prosthesis	Implants lost 5 years after application of the definitive prosthesis	Implants lost 10 years after application of the definitive prosthesis
1	41	7	Screwed	0	0	0	0
2	45	7	Screwed	0	0	0	1
3	40	6	Screwed	0	0	0	0
4	42	5	Cemented	0	0	0	0
5	25	2	Cemented	0	0	0	0
6	55	5	Cemented	0	0	0	0
7	70	5	Cemented	0	2	0	1
8	53	5	Cemented	0	0	0	0

DISCUSSION

Implant rehabilitation of the posterior region of the maxilla often requires particular attention from the clinician, given the frequent reduction in the height of residual bone as a consequence of the pneumatization of the maxillary sinus following dental extractions. To overcome these anatomical limitations, the maxillary sinus lift technique is the main surgical procedure capable of obtaining a vertical bone gain in the posterior maxilla to insert fixtures.

In the literature, the percentage of implant success corresponds to an equal percentage of success of the maxillary sinus lift and osseointegration of the grafted material (31).

Radiological and clinical criteria are therefore taken into consideration to establish the success or failure of implant therapy. According to the scheme drawn up during "The International Congress of Oral Implantologists Pisa, Italy Consensus Conference", implant success (i.e., understood as the optimal condition for the permanence of the implant in the oral cavity) and failure (i.e., the loss of implant or the need to remove it), are evaluated based on:

- presence of pain on palpation, percussion, or function;
- clinical mobility;
- peri-implant bone loss visible radiographically;
- presence of exudate around the implant.

The introduction of regenerative techniques in odontostomatological surgery has allowed the rehabilitation of edentulous areas that would otherwise be impossible to rehabilitate with fixed solutions.

The maxillary sinus lift has been developed over time with different techniques, which involved the insertion of autologous or non-autologous bone in the subantral space, as well as the non-use of graft material. The use of autologous bone as a graft material for maxillary sinus lift has the advantage of supporting the sinus membrane and acting as an osteo-conductive support during bone formation by osteoblasts. This property, and the presence of osteogenic progenitor cells within the graft material, has led to this material being preferred for sinus membrane elevation. In the present study, the anterior iliac crest was chosen as the sampling site, given the need to re-establish large quantities of bone volume.

The insufficient quantity of residual bone crest at the level of the posterior maxilla has also led to the need to carry out implant rehabilitation at a later stage compared to the application of the bone graft in the subantral space. Implant insertion was done once the graft material matured and guaranteed adequate primary stability.

In the study by Yamamichi et al. on 625 implants, 53% were inserted at the same time as the sinus lift, while the remaining 47% were inserted after healing, on average 6.5 months after the sinus lift. An average survival rate of 96.4% is detected, while 3.6% present mobility before prosthetic loading, indicating therapeutic failure. All cases of failure corresponded to implant insertion at the same time as maxillary sinus lift, regardless of the implant surface and the graft applied. The authors attribute this result to the possibility that two-stage implant insertion can increase the probability of implant success and overcome limitations due to particularly advanced bone atrophy present in the pre-surgical period (32).

The use of piezoelectric instrumentation for the creation of the lateral sinus access window and the lifting of the sinus membrane has allowed a clear reduction in the risk of perforation of the sinus membrane, one of the main factors of implant failures.

The absence of perforation of the sinus membrane during major sinus lift is also a strictly operator-dependent variable, as it is closely linked to the surgeon's manual ability during the surgical operation. In the present study, the lack of onset of the complication of perforation of the sinus membrane is, in fact, to be attributed, in addition to the action of the piezoelectric instrumentation, to the presence of a single operator.

The main advantage of ultrasound technology is attributable to the selective cutting of mineralized tissues and the immediate cessation of operation of the piezoelectric device in case of accidental contact with the sinus membrane (23).

Wallace et al. report a reduction in perforation of the sinus membrane following sinus lift, from 30% with the use of rotary instruments to only 7% with the aid of piezoelectric instrumentation (33).

Comparing rotary and piezoelectric instrumentation in the execution of maxillary sinus lift, Barone et al. found a reduced percentage of membrane perforations compared to rotary instrumentation (23% vs 30%) but a greater time requirement in the execution of osteotomy cuts via piezosurgery (34).

In several studies, the survival of implants inserted in the context of large sinus lifts performed using piezosurgery has been investigated. In a study conducted on 53 maxillary sinuses raised through the use of piezoelectric technology and the insertion of autologous bone or Bio-oss, Blus et al. found a survival rate of 96.6%, six months after the operation upward. In subsequent checks 3, 6 and 12 months after prosthetic loading, none of the 117 implants inserted failed (35).

In addition to a clear reduction in the percentage of perforations of the sinus membrane during sinus augmentation, piezoelectric instrumentation also made it possible to reduce post-operative pain and edema, causing less discomfort in the treated patients (36). It also favors the primary and secondary stability of the inserted implants, thanks to the ability to create bone-cutting surfaces without signs of cellular necrosis. For the implant to undergo complete osteointegration, it is, in fact, necessary for the graft positioned beneath the Schneiderian membrane to present a good percentage of viable bone and osteogenic cells, that is between 25 and 35% (37).

Numerous studies have been carried out to evaluate the survival of implants inserted into raised maxillary sinuses through the insertion of different types of grafting materials. In a literature review, Al-Nawa et al. analyze implant survival in implant augmentations performed through the insertion of autologous bone or bone substitutes as graft materials, for a total of 4687 implants. Implant success is estimated at 98.6% ± 2.6 for augmentations performed through the insertion of bone substitutes, 88.6% ± 4.1 in cases in which autologous bone and bone substitutes are mixed and 97.4% ± 2.2 for augmentations performed by insertion of autologous bone alone. No statistically significant difference in implant success is therefore detected between the two surgical techniques (38).

The success of maxillary sinus lifts, regardless of the type of graft material inserted into the subantral space, has been confirmed by numerous literature reviews. Among these, Chiapasco et al. analyze 59 studies in which 13889 implants are inserted into raised maxillary sinuses by inserting autologous bone or bone substitutes, alone or mixed. An implant survival rate between 60-100% was detected, with a pitch of 98%. It is also confirmed that the insertion of different graft materials beneath the sinus membrane does not influence the average implant survival in a statistically significant manner. The application of graft materials in the context of the sinus lift, therefore, appears to be an operation that leads to a low percentage of complications, mainly linked to a possible perforation of the sinus membrane, which, according to the same study, occurs in 10% of patients cases. The loss of the graft material occurs in less than 1% of cases, while post-operative sinusitis is detected in a range between 0-27% of cases, generally in maxillary sinuses already previously affected (39).

Regardless of the graft material used, the persistence of sinus graft height stability was confirmed by Jensen et al. (40), which, during a 3.2-year follow-up of 349 implants inserted into raised maxillary sinuses, revealed a minimal reduction in the height of the graft ranging from 0.8 mm in the case of insertion of autologous bone mixed with alloplastic material, to 2.1 mm in the case of autologous material only. Similar findings arose from further studies aimed at analyzing the long-term stability of sinus grafts (41, 42).

In a 5-year longitudinal study, Wiltfang et al. analyze the difference, in terms of bone resorption and implant survival, of the insertion procedure of onlay bone graft and maxillary sinus lift using autologous bone graft to rehabilitate the posterior maxilla.. Out of 349 implants inserted in 61 patients, the survival obtained following maxillary sinus lift was 94.6%, while when an onlay graft was applied, the survival of the 235 implants was 91.5%. Sinus lift also allowed a lower percentage of bone resorption to be obtained (43).

CONCLUSIONS

Implant rehabilitation of the posterior areas of the atrophic jaws requires a carefully designed treatment plan. The major problem arises when the pneumatization of the maxillary sinus does not allow direct fixture insertion. The maxillary sinus lift technique is a pre-prosthetic surgical procedure that can be used effectively to achieve adequate bone height for implant-prosthetic rehabilitation.

In the present study, lateral maxillary sinus lift was used, a safe and predictable surgical procedure that guarantees high rates of success and implant survival. The ten-year implant survival percentage of implants inserted six months after maxillary sinus lift, performed using piezoelectric technology and insertion of autologous bone from the iliac crest, appears to be comparable with that obtained from international literature.

Given the low percentage of resorption, excellent long-term stability and high integration, it was decided to proceed with the insertion of autologous bone into the subantral space. The harvest from the iliac crest was dictated by the need to rehabilitate large edentulous areas. Despite the extensive resorption, the bone chips inserted in the context of maxillary sinus lift demonstrated optimal integration in all cases presented, without any associated complications.

In the literature, similar implant survival rates are associated with different graft materials placed in the subantral space. The absence of a statistically significant difference between the success of large maxillary sinus lifts performed through the insertion of autologous bone or bone substitutes indicates the effectiveness of this surgical technique regardless of the graft material used. Although conventional surgical techniques, such as the use of rotary instruments which reduce operating times, ultrasonic bone surgery is currently a method with high predictability and good short and long-term results.

In line with what has been stated in international literature, the use of piezoelectric technology to perform maxillary sinus lift has made it possible to significantly reduce the probability of perforation of the sinus membrane, a complication which did not occur in any case during this study.

Conflicts of interest

The authors certify no conflict of interest with any financial organization regarding the material discussed in the manuscript.

REFERENCES

1. Lekholm U, Adell R, Lindhe J, et al. Marginal tissue reactions at osseointegrated titanium fixtures. *International Journal of Oral and Maxillofacial Surgery*. 1986;15(1):53-61. doi:https://doi.org/10.1016/s0300-9785(86)80011-4
2. Misch CE. Contemporary implant dentistry (ed 2) 1999. St. Louis, MO: Mosby Incs.
3. Urist MR. Bone: Formation by Autoinduction. *Science*. 1965;150(3698):893-899.

doi:https://doi.org/10.1126/science.150.3698.893
4. Reddi AH, Wientroub S, Muthukumaran N. Biologic Principles of Bone Induction. *Orthopedic Clinics of North America*. 1987;18(2):207-212. doi:https://doi.org/10.1016/s0030-5898(20)30384-9
5. Burchardt H. The Biology of Bone Graft Repair. *Clinical Orthopaedics and Related Research*. 1983;(174):28-42. doi:https://doi.org/10.1097/00003086-198304000-00005
6. Ilizarov GA. The Tension-Stress Effect on the Genesis and Growth of Tissues. *Clinical Orthopaedics and Related Research*. 1989;238:249-281. doi:https://doi.org/10.1097/00003086-198901000-00038
7. Dahlin C, Linde A, Gottlow J, Nyman S. Healing of bone defects by guided tissue regeneration. *Plastic and Reconstructive Surgery*. 1988;81(5):672-676. doi:https://doi.org/10.1097/00006534-198805000-00004
8. Nyman SR, Lang NP. Guided tissue regeneration and dental implants. *Periodontology 2000*. 1994;4(1):109-118. doi:https://doi.org/10.1111/j.1600-0757.1994.tb00011.x
9. Hammerle CHF, Jung RE, Feloutzis A. A systematic review of the survival of implants in bone sites augmented with barrier membranes (guided bone regeneration) in partially edentulous patients. *Journal of Clinical Periodontology*. 2002;29(s3):226-231. doi:https://doi.org/10.1034/j.1600-051x.29.s3.14.x
10. Gi T. Reconstruction of the Mandible with Free Composite Iliac Bone Grafts. *Annals of plastic surgery*. 1982;9(5):361-376. doi:https://doi.org/10.1097/00000637-198211000-00003
11. Boyne PJ, Kruger GO. Fluorescence microscopy of alveolar bone repair. *Oral Surgery, Oral Medicine, Oral Pathology*. 1962;15(3):265-281. doi:https://doi.org/10.1016/0030-4220(62)90105-6
12. Simion M, Fontana F, Giulio Rasperini, Maiorana C. Long-term evaluation of osseointegrated implants placed in sites augmented with sinus floor elevation associated with vertical ridge augmentation: a retrospective study of 38 consecutive implants with 1- to 7-year follow-up. *PubMed*. 2004;24(3):208-221.
13. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. *Compend Contin Educ Dent* . 1980;38(8):613-616.
14. Summers RB. A new concept in maxillary implant surgery: the osteotome technique. *Compendium (Newtown, Pa)*. 1994;15(2):152, 154-156, 158 passim; quiz 162.
15. Testori, Weinstein, Wallace. La chirurgia del seno mascellare e le alternative terapeutiche Acme. 2005. Acme.
16. Tatum H. Maxillary and sinus implant reconstructions. *Dental Clinics of North America*. 1986;30(2):207-229.
17. Catuna MC. Sonic energy. A possible dental application. Preliminary report of an ultrasonic cutting method. *Ann Dent*. 1953;112:256-260.
18. Mararow H. Bone repair after experimentally produced defects. *Journal of Oral Surgery*. 1960;18:107-114.
19. Mcfall TA, Yamane GM, Burnett GW. Comparison of the cutting effect on bone of an ultrasonic cutting device and rotary burs. *Journal of oral surgery, anesthesia, and hospital dental service*. 1961;19:200-209.
20. Horton JR, Tarpley TM, Wood LD. The healing of surgical defects in alveolar bone produced with ultrasonic instrumentation, chisel, and rotary bur. *Oral Surg Oral Med Oral Pathol*. 1975;39(4):536-546. doi:https://doi.org/10.1016/0030-4220(75)90192-9
21. Torrella F, Pitarch J, Cabanes G, Anitua E. Ultrasonic ostectomy for the surgical approach of the maxillary sinus: a technical note. *The International Journal of Oral & Maxillofacial Implants*. 1998;13(5):697-700.
22. Vercellotti T. Piezoelectric surgery in implantology: a case report--a new piezoelectric ridge expansion technique. *The International Journal of Periodontics & Restorative Dentistry*. 2000;20(4):358-365.
23. Vercellotti T, De Paoli S, Nevins M. The piezoelectric bony window osteotomy and sinus membrane elevation: introduction of a new technique for simplification of the sinus augmentation procedure. *J Periodontics Restorative Dent*. 2001;21(6):561-567.
24. Vercellotti T. Caratteristiche tecnologiche e indicazioni cliniche della chirurgia ossea piezoelettrica - Minerva Stomatologica 2004 May;53(5):207-14. Minervamedica.it.
25. Albrektsson T, Johansson C. Osteoinduction, osteoconduction and osseointegration. *European Spine Journal*. 2001;10(0):S96-S101. doi:https://doi.org/10.1007/s005860100282
26. Becker W, Becker BE, Newman MG, Nyman S. Clinical and microbiologic findings that may contribute to dental implant failure. *PubMed*. 1990;5(1):31-38.
27. Timmenga NM, Raghoebar GM, Boering G, van Weissenbruch R. Maxillary sinus function after sinus lifts for the insertion of dental implants. *Journal of Oral and Maxillofacial Surgery*. 1997;55(9):936-939. doi:https://doi.org/10.1016/s0278-2391(97)90063-x
28. Sekine H. Mobility characteristics and tactile sensitivity of osseointegrated fixture-supporting systems. *Tissue integration in oral and maxillofacial reconstruction*. Published online 1986:326-332.
29. Zitzmann NU, Berglundh T. Definition and prevalence of peri-implant diseases. *Journal of Clinical Periodontology*. 2008;35(8SUPPL):286-291. doi:https://doi.org/10.1111/j.1600-051x.2008.01274.x
30. Fokkens WJ, Lund VJ, Hopkins C, et al. European Position Paper on Rhinosinusitis and Nasal Polyps 2020. *Rhinology journal*. 2020;0(0):1-464. doi:https://doi.org/10.4193/rhin20.600
31. Jensen OT, Shulman LB, Block MS, Iacono VJ. Report of the Sinus Consensus Conference of 1996. *Int J Oral Maxillofac Implants* . 1998;13 Suppl(SUPPL):11-45.
32. Nobuyuki Yamamichi, Tatsumasa Itose, Neiva R, Wang HL. Long-term evaluation of implant survival in augmented

sinuses: a case series. *Int J Periodontics Restorative Dent*. 2008;28(2):163-169.
33. Wallace SS, Tarnow DP, Froum SJ, et al. Maxillary Sinus Elevation by Lateral Window Approach: Evolution of Technology and Technique. *Journal of Evidence Based Dental Practice*. 2012;12(3):161-171. doi:https://doi.org/10.1016/s1532-3382(12)70030-1
34. Barone A, Santini S, Marconcini S, Giacomelli L, Gherlone E, Covani U. Osteotomy and membrane elevation during the maxillary sinus augmentation procedure. *Clinical Oral Implants Research*. 2008;19(5):511-515. doi:https://doi.org/10.1111/j.1600-0501.2007.01498.x
35. Blus C, Szmukler-Moncler S, Khoury P, Orrù G. Immediate Implants Placed in Infected and Noninfected Sites after Atraumatic Tooth Extraction and Placement with Ultrasonic Bone Surgery. *Clinical Implant Dentistry and Related Research*. 2013;17:e287-e297. doi:https://doi.org/10.1111/cid.12126
36. Delilbasi C, Gurler G. Comparison of Piezosurgery and Conventional Rotative Instruments in Direct Sinus Lifting. *Implant Dentistry*. 2013;22(6):662-665. doi:https://doi.org/10.1097/id.0000000000000001
37. Wheeler SL. Sinus augmentation for dental implants: The use of alloplastic materials. *Journal of Oral and Maxillofacial Surgery*. 1997;55(11):1287-1293. doi:https://doi.org/10.1016/s0278-2391(97)90186-5
38. Al-Nawas B, Schiegnitz E. Augmentation procedures using bone substitute materials or autogenous bone - a systematic review and meta-analysis. *European Journal of Oral Implantology*. 2014;7 Suppl 2:S219-234.
39. Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. *The International Journal of Oral & Maxillofacial Implants*. 2009;24 Suppl:237-259.
40. Jensen OT, Adams MW. Anterior Sinus Grafts for Angled Implant Placement for Severe Maxillary Atrophy as an Alternative to Zygomatic Implants for Full Arch Fixed Restoration: Technique and Report of 5 Cases. *Journal of Oral and Maxillofacial Surgery*. 2014;72(7):1268-1280. doi:https://doi.org/10.1016/j.joms.2014.02.006
41. Hatano N, Sennerby L, Lundgren S. Maxillary Sinus Augmentation Using Sinus Membrane Elevation and Peripheral Venous Blood for Implant-Supported Rehabilitation of the Atrophic Posterior Maxilla: Case Series. *Clinical Implant Dentistry and Related Research*. 2007;9(3):150-155. doi:https://doi.org/10.1111/j.1708-8208.2007.00043.x
42. Block MS, Kent JN, Kallukaran FU, Thunthy KH, Weinberg RA. Bone maintenance 5 to 10 years after sinus grafting. *Journal of Oral and Maxillofacial Surgery*. 1998;56(6):706-714. doi:https://doi.org/10.1016/s0278-2391(98)90801-1
43. Wiltfang J, Schultze-Mosgau S, Nkenke E, Thorwarth M, Neukam FW, Schlegel KA. Onlay augmentation versus sinuslift procedure in the treatment of the severely resorbed maxilla: a 5-year comparative longitudinal study. *International Journal of Oral and Maxillofacial Surgery*. 2005;34(8):885-889. doi:https://doi.org/10.1016/j.ijom.2005.04.026