Malpositioned Osseointegrated Implants Relocated with Segmental Osteotomies: A Retrospective Analysis of a Multicenter Case Series with a 1- to 15-Year Follow-Up

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ABSTRACT

Purpose: This multicenter case series evaluates retrospectively the clinical outcomes of malpositioned implants surgically relocated in a more convenient position by segmental osteotomies.

Materials and Methods: Authors who published, on indexed journals or books, works about malpositioned implant correction by segmental osteotomies were contacted. Five centers, out of 11 selected, accepted to participate in this study. The dental records of patients who underwent implant relocation procedures were reviewed. Implant survival rates were analyzed and a blinded assessor examined clinical photos and periapical radiographs to evaluate esthetic outcome (pink esthetic score [PES]) and changes of marginal bone level over time. Patients were requested to fill a verbal rating scale form about discomfort, compliance, and satisfaction related to the procedure.

Results: Fifteen malpositioned implants relocated by segmental osteotomies were followed for a period ranging from 1 to 15 years (mean 6.0 ± 3.9 years). The overall implant survival rate from baseline to the last follow-up visit was 100%. The mean marginal bone loss was 0.36 mm at the 12-month follow-up visit and no relevant further changes were observed at the following examinations. Significant esthetic improvement was recorded at 1-year examination with PES evaluation ($p < .0001$). Patients' feedback described this procedure as not excessively invasive and uncomfortable, reporting a high final satisfaction rate.

Conclusions: The present study suggests that implant relocation with segmental osteotomies could be an effective alternative method to correct the position of unrestorable malpositioned implants in a single-stage surgery.

KEY WORDS: implant relocation, malpositioned implants, piezosurgery, segmental osteotomy

INTRODUCTION

When an osseointegrated implant is poorly positioned, it can be very difficult or even impossible to achieve satisfactory esthetics and functional prosthetic outcomes.[1,2] Moderate malpositions can be successfully treated by using esthetic custom abutments[3] or by planning individualized frameworks, which, on occasion, help in reaching an acceptable final clinical result.[4–6]

If prosthetic corrections are not sufficient, limited options are available for the solution of challenging restorative problems. In these situations, the malpositioned implant can be left "sleeping" under the soft tissue[7] or resubmerged completely into the bone,[8] thus

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forgoing its support in prosthetic rehabilitation, or it can be surgically removed and replaced with a new implant inserted in the proper position.

Unfortunately, implant removal frequently results in hard and soft tissue defects requiring corrections with advanced regeneration procedures prior to inserting a new fixture.

In these unfavorable cases, an alternative is represented by implant relocation. This surgical option consists of mobilizing the malpositioned implant together with the surrounding bone by way of segmental osteotomies and then relocating the block in the correct position in order to allow for an acceptable prosthetic rehabilitation. This technique, derived from segmental osteotomies procedures used in orthodontic and orthognatic surgery,[9–12] has been described in the literature with variations in a few case reports. The shifting of the malpositioned implant is usually obtained by a single translational and/or rotational movement of the bony-implant block, which is immediately stabilized in the new position by a rigid fixation.[13–24] Other authors prefer to induce a gradual movement by applying orthodontic forces or distraction osteogenesis procedures to the mobilized block.[25–28]

The aim of this retrospective study was to conduct a multicenter analysis on the outcomes of implant relocation technique at different follow-up periods, considering factors related to the implant (survival rate and marginal bone loss), to the surrounding tissues (esthetic outcome), and to the patients' feedback (discomfort, compliance, and satisfaction).

MATERIALS AND METHODS

Experimental Design

The electronic databases MEDLINE, EMBASE, Cochrane Library, and SciVerse Scopus were searched up to the 15th of December 2010 for papers on malpositioned osseointegrated implants corrected in a single-stage surgery by segmental osteotomies with a follow-up of at least 1 year in function. Screening of eligible works and assessment of their methodological quality were conducted at the Coordinating Center (Trieste University, Italy) in duplicate and independently by two authors.

First authors of the selected works were contacted by e-mail or telephone and asked to contribute in carrying out this retrospective study.

All of the patients treated consecutively by Coordinating and selected Clinical Centers for correction of implant malpositions with segmental osteotomies were eligible for entering this study.

The inclusion criteria were the following:

- the possibility to schedule a visit to check the present conditions of the repositioned implant;
- minimum follow-up of 1 year in function after implant relocation surgery.

The following documentation was requested from the centers:

- preoperative and postoperative periapical radiographs (after at least 6 months of healing) of a sufficient quality to clearly visualize peri-implant bone levels. All eventual additional radiographs, including the last available (maximum follow-up), were used to perform evaluations at different time intervals. These were collected and sent to the Coordinating Center for analysis.
- for implants placed in esthetic areas: preoperative and postoperative photographs (after at least 6 months of healing) of a sufficient quality to apply the pink esthetic score (PES) evaluation[29] by a blinded examiner. All eventual additional photographs were used to perform evaluations at different time intervals. These were collected and sent to the Coordinating Center, including the last available photograph (maximum follow-up).
- patients were asked to fill a form with their feedback about treatment outcomes (verbal rating scale [VRS] score about discomfort, compliance, and satisfaction on a four-point VRS).

Data Collection and Analysis

A case report form (CRF) was arranged to collect data pertinent to this analysis. For each clinical center, one trained clinical operator was involved in data collection (filling the CRFs, collecting patients' feedback, and performing and collecting periapical radiographs and photographs). Filled CRFs, radiographs, and photographs were sent to the Coordinating Center (as original or high-resolution scanned copies), where a trained and calibrated examiner completed all radiographic measurements and esthetical evaluations.

This examiner was not involved in the surgical procedures and was blinded either to the provenance or to the observation interval of each radiograph and photograph.

Each implant was classified either as success or failure according to the criteria stated by Albrektsson and colleagues.[30]

All available intraoral radiographs from baseline and annual checkups were analyzed with regard to marginal bone level and bone loss. At the Coordinating Center, all traditional radiographs were scanned and digitized. Stored images were displayed on a monitor and linear measurements of bone levels were performed with the help of a cursor (errors of perspective were corrected, knowing the exact length of each implant). The distance between the top of the implant shoulder and the first visible bone-implant contact (Distance Implant Bone crest [DIB]) on the mesial and distal aspects of each implant was measured.[31,32]

When the implant was positioned in an esthetic area, photographs were examined to apply the PES, evaluating the esthetic outcome of the implant relocation procedure.

Statistical Analysis

All data coming from CRFs, radiographic measurements, and esthetical evaluations were transferred into a single electronic dataset, and all analyses were performed using SPSS, version 16.0 (SPSS Inc., Chicago, IL, USA). The patient was regarded as the statistical unit.

Kolmogorov-Smirnov test was used to evaluate the normal distribution fitting of each variable.

Data are expressed as mean ± standard deviation and were evaluated by using the Student's *t*-test for paired and independent observations. The level of significance was set at 5%.

RESULTS

Study Population

Eleven centers were selected and asked to participate in this study: five out of 11, distributed in four continents, gave a positive response. Between 1996 and 2010, 15 patients (1 man and 14 women), aged from 18 to 74 years (mean 49.8 ± 16.6 years), were consecutively treated in the five selected centers with implant relocation procedures to correct severe fixture malpositions. All of the patients were nonsmokers and 14 out of 15 had not significant anamnestic remarks (one patient was diabetic type 2, since 8 years, in good metabolic control).

Surgical Technique

Under local anesthesia, a full-thickness mucoperiosteal flap was elevated buccally, leaving the lingual aspect undisturbed in order to completely preserve vascular support deriving from this side. In most cases, malpositioned implants exhibited facial bone dehiscence and/or fenestration defects that were not treated. Two full-thickness longitudinal osteotomies parallel to the long axis of the malpositioned implant were performed mesially and distally with respect to the fixture through the buccal and palatal cortical plates. These bone cuts were performed with burs and chisel in four cases, with a saw (Aesculap, B.Braun Melsungen AG, Melsungen, Germany) in three cases, and with a piezoelectric device (Piezosurgery, Mectron, Carasco, Italy) in the remaining eight implants. Lastly, an apical corticotomy perpendicular to the long axis of the malpositioned implant was performed by connecting the two longitudinal osteotomies (Figure 1): a progressive pressure applied in palatal direction or the gentle use of a surgical mallet was sufficient to produce a green-stick fracture of the bone-implant block, completing its mobilization (Figure 2).

Once the malpositioned implant was gently moved into the planned position, it was fixated by using devices anchored to the bone or to adjacent teeth or implants

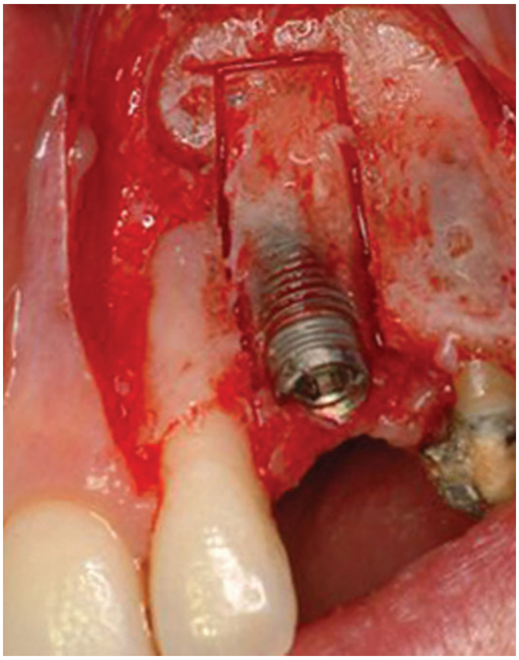

Figure 1 Mesial and distal full-thickness osteotomies (through the buccal and palatal cortical plates), connected by an apical corticotomy, define the bone-implant block to be repositioned.

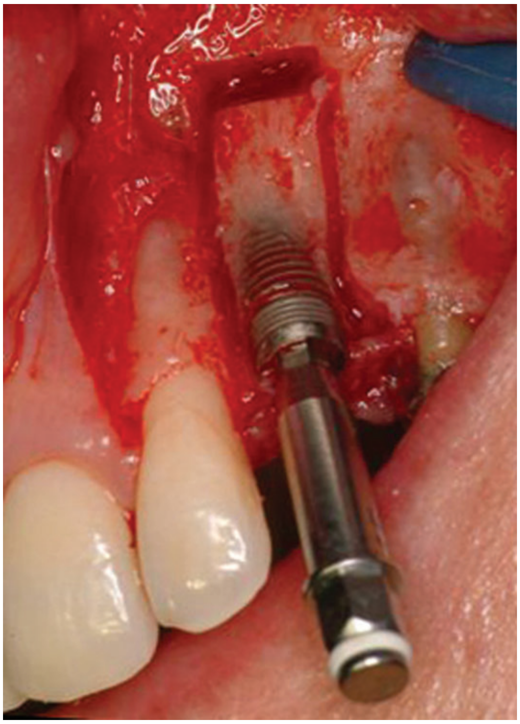

Figure 2 A progressive pressure applied in palatal direction is sufficient to produce a green-stick fracture of the block.

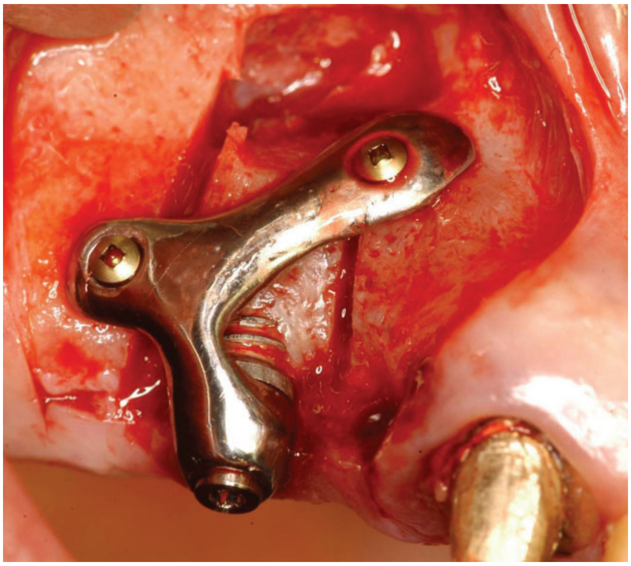

Figure 4 The stabilization of the repositioned block can be also achieved by means of miniplates or custom-made devices anchored to the bone.

(Figures 3 and 4). In one case, the relocated block found stability without needing any fixation.

In most cases, osteotomy gaps were filled with osteoconductive biomaterials (xenografts, allografts, or autografts) in order to promote cell migration from the adjacent bone, thus favoring osseous healing process.

The healing period, before loading the relocated implants, varied from 6 to 32 weeks (mean 16.5 ± 9.4 weeks).

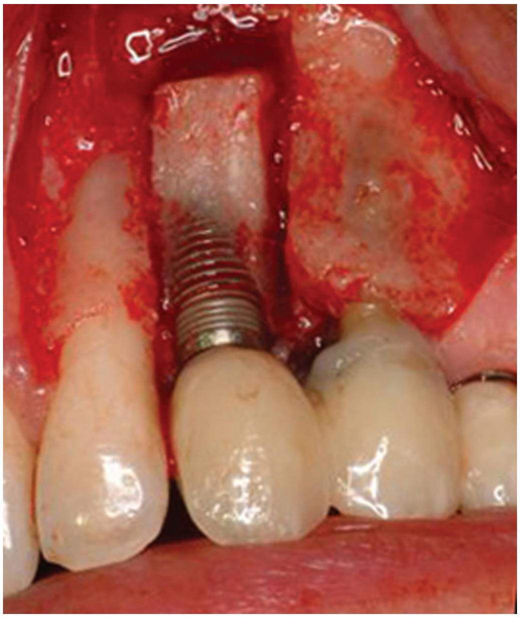

Figure 3 The relocated block is firmly stabilized using a custom-made prosthetic framework anchored to an adjacent tooth (#24) and to an implant (#25).

Clinical Outcomes

No dropouts were recorded during the entire period of observation: nevertheless, the radiographic evaluation in three patients and the patient feedback analysis in two patients were not available, due to lack of appropriate documentation. In total, inadequate position of 15 implants was surgically corrected in a single-stage procedure by segmental osteotomies: 13 implants were located in maxillary esthetic areas (from premolars to incisors) and two were inserted in the mandibular anterior zone. Eight implants supported single crowns, five implants were part of implant-supported fixed partial prostheses, and two implants were used as abutments in overdentures.

Specifications concerning time and details of surgeries, implant sites and length, and healing features are listed in Table 1.

A cumulative implant survival rate of 100% was observed over a period of up to 15 years (mean 6.0 ± 3.9 years). At the last examination, all the patients referred satisfactory function of the treated implants, without any foreign body sensation, pain, or dysesthesia. The

TABLE 1 Overview of 15 Malpositioned Implants Relocated in a Single-Stage Surgery by Five Centers

Center	Patient	Age	Site	Implant Length	Insertion Year	Relocation Year	Osteotomic Technique	Type of Fixation	Grafting Material	Healing (Weeks)
1	L.D.	25	23	13	2004	2005	Piezoelectric	Dental	Autologous bone	20
	L.P.	74	15	13	2005	2008	Piezoelectric	Bone plate	Calcium phosphate	24
	R.B.	65	11	13	2007	2008	Piezoelectric	Bone plate	Bovine bone	24
	P.E.	52	25	13	2008	2009	Piezoelectric	Dental	Allogeneic bone	24
	A.C.	47	23	13	2007	2010	Piezoelectric	Dental	Allogeneic bone	20
2	M.W.	26	21	10	1995	1996	Burs/chisel	Bone plate	None	32
	D.P.	52	14	13	1999	2000	Burs/chisel	Bone plate	Autologous bone	28
	C.G.	55	12	12	2003	2003	Burs/chisel	None	None	24
3	A.B.	60	33	12	2001	2003	Saw	Bone plate	Autologous bone	6
	C.P.	34	23	13	2005	2006	Saw	Dental	Autologous bone	12
	K.H.	65	43	12	2006	2007	Piezoelectric	Bone plate	Autologous bone	8
4	F.C.	18	22	13	1998	2000	Burs/chisel	Dental	Bovine bone	6
5	Y.Z.	54	22	10	2005	2006	Saw	Bone plate	Bovine bone	8
	T.Z.	59	12	11.5	2007	2007	Piezoelectric	Bone plate	Bovine bone	6
	K.A.	61	12	13	2009	2009	Piezoelectric	Bone plate	Bovine bone	6

intraoral examination demonstrated healthy peri-implant tissues without any signs of inflammation.

Mean marginal bone loss at the 12-month follow-up visit was 0.36 ± 0.52 mm (range, −0.6 to 1.2 mm). DIB scores for every single implant are reported in Table 2. At the following examinations, all of the implants showed no further crestal bone loss within the limits of the periapical radiographic measurements. In some cases, long-term controls demonstrate a

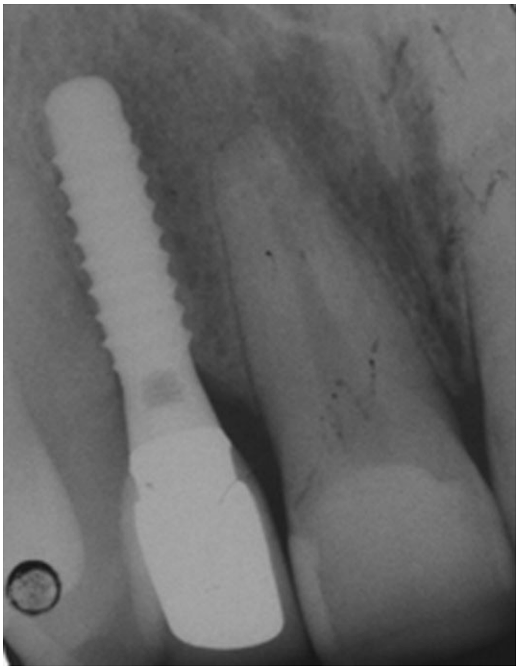

Figure 5 Periapical radiograph performed 12 months after implant relocation procedure (patient C.G., November 2004). The osteotomic cuts appear perfectly closed.

Figure 6 Periapical radiograph performed 8 years after implant relocation procedure (patient C.G., May 2011). Improvement of the marginal bone levels is evident when compared with the previous follow-up (Figure 5).

TABLE 2 Bone Levels with DIB Results (Radiographic) at Baseline and 1 Year after the Relocation Procedure

	Baseline DIB (mm)		1-Year DIB (mm)		Bone Loss (mm)	
Patient	Mesial	Distal	Mesial	Distal	Mesial	Distal
L.D.	0.0	3.7	−0.4	3.1	−0.4	−0.6
L.P.	1.8	2.0	2.3	2.5	0.5	0.5
R.B*	4.9	3.9	4.6	3.8	−0.3	−0.1
P.E.	0.0	2.2	0.5	2.8	0.5	0.6
A.C.	0.0	0.0	0.9	1.2	0.9	1.2
M.W.	1.5	2.0	1.5	1.5	0.0	−0.5
D.P	0.0	0.0	1.1	0.5	1.1	0.5
C.G.	1.6	1.6	1.7	1.7	0.1	0.1
A.B.	0.8	1.3	1.8	2.1	1.0	0.8
C.P.	—		—		—	
K.H.	—		—		—	
F.C.	—		—		—	
Y.Z.	2.2	1.9	3.1	2.8	0.9	0.9
T.Z.	2.2	1.2	2.3	1.5	0.1	0.3
K.A.	0.9	0.4	1.2	0.6	0.3	0.2
Mean	1.50 ± 1.32		1.86 ± 1.15		0.36 ± 0.52	

*Transgingival implant.
DIB = Distance Implant Bone crest.

progressive improvement of the marginal bone levels (Figures 5 and 6).

The PES evaluation was performed on 12 implants, positioned in esthetic areas. Mean PES value at baseline was 1.7 ± 1.2 (range, 0–4); at the 12-month follow-up visit, it was 8.7 ± 2.2 (range, 6–13) (Figures 7 and 8). The difference between PES values at baseline and 1 year after the relocation procedure was highly significant ($p < .0001$). Additional evaluations performed at different time intervals demonstrated good soft tissue stability and maintenance of the esthetic outcome overtime in all cases examined (Figures 9–11).

Finally, patients' feedback about the outcomes of this procedure was evaluated. According to the VRS score, 46% of the subjects reported very high or high discomfort and 54% low or no discomfort. Twenty-three percent would never or were reluctant to undergo this procedure again, whereas 77% would undergo this

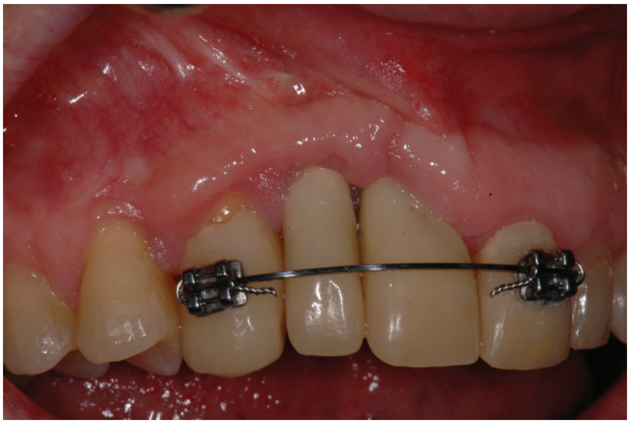

Figure 7 Preoperative situation of patient R.B. Poor implant positioning resulted in an unacceptable esthetic outcome (pink esthetic score = 2).

Figure 8 Postoperative outcome of patient R.B. After implant relocation procedure, it was possible to recover the malpositioned implant with a significant esthetic improvement (pink esthetic score = 11).

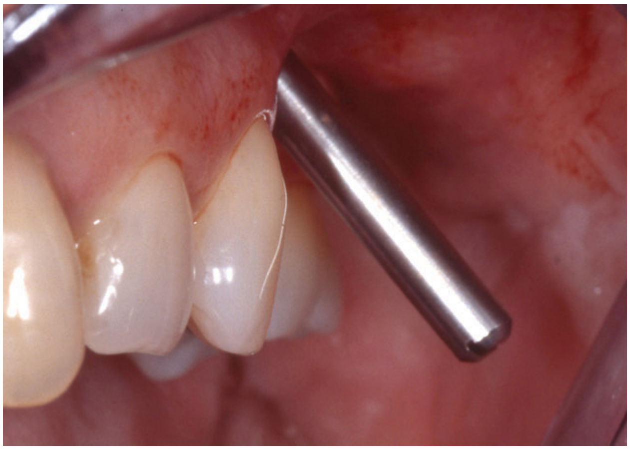

Figure 9 Preoperative situation of patient D.P. An acceptable prosthetic result was impossible to obtain due to errors in implant insertion (faciopalatal positioning, depth, and angulation).

Figure 11 A control scheduled 11 years after implant repositioning, demonstrating good soft tissue stability and maintenance of the esthetic outcome overtime (patient D.P., June 2011).

surgery again without particular problems. There were 15% of the patients who were not fully satisfied of the final result, whereas 85% were satisfied or very satisfied. The complete VRS outcomes are listed in Table 3.

The only surgical variable significantly influencing patient feedback about discomfort was related to the osteotomic technique: the group in which a piezoelectric device was used reported a mean $VRS_{discomfort}$ (1.9 ± 1.1) significantly lower than the group operated with burs or saws (3.0 ± 0.7) ($p < .05$). No other significant correlations were observed between any surgical variable and $VRS_{discomfort}$, $VRS_{compliance}$, or $VRS_{satisfaction}$.

DISCUSSION

An accurate surgical planning is a fundamental prerequisite in obtaining successful treatment outcomes in implant dentistry, especially when dealing with esthetic areas.[33,34] The clinician, before starting the surgical procedure, has to be aware of the exact three-dimensional position, angulation, and depth in which the implant

Figure 10 Final prosthetic restoration 12 months after implant relocation procedure, showing a satisfactory functional and esthetic outcome (patient D.P., November 2001).

TABLE 3 Patients' Feedback About Discomfort, Compliance, and Satisfaction

Patient	$VRS_{discomfort}$	$VRS_{compliance}$	$VRS_{satisfaction}$
L.D.	1	4	4
L.P.	1	4	4
R.B.	2	4	4
P.E.	1	3	2
A.C.	2	3	4
M.W.	3	1	3
D.P.	3	1	3
C.G.	2	4	3
A.B.	4	4	4
C.P.	—	—	—
K.H.	—	—	—
F.C.	3	2	2
Y.Z.	3	4	3
T.Z.	2	4	4
K.A.	4	4	3
Mean	2.38 ± 1.04	3.23 ± 1.17	3.31 ± 0.75

$VRS_{discomfort}$: 1 = no discomfort; 2 = low discomfort; 3 = high discomfort; 4 = very high discomfort.
$VRS_{compliance}$: 1 = I would never undergo this procedure again; 2 = I would undergo this procedure, but expecting pain and discomfort; 3 = I would undergo this procedure, but I would delay it as far as possible; 4 = I would undergo this procedure without any problem.
$VRS_{satisfaction}$: 1 = not satisfied at all; 2 = partially satisfied; 3 = satisfied; 4 = very satisfied.
VRS = verbal rating scale.

has to be inserted and of the type of implant to be used. A strict planning protocol should prevent the insertion of implants where the bone is insufficient or, maybe even worse, where the bone volume is sufficient to place the fixture but inadequate to allow for a satisfactory prosthetic outcome.

Nevertheless, several factors including lack of surgical planning, surgical guide inaccuracies, inexperience, growth-related factors, or "bone-driven" insertion of the implant can result in osseointegrated implants placed in positions that are very hard or even impossible to use for an acceptable restoration. If the results of all prosthetic alternatives are unsatisfactory and the implant cannot be "put to sleep" under the soft tissues, it has to be removed prior to inserting a new implant in the correct position. The standard approach to remove an osseointegrated implant usually requires an invasive surgery and damage to the surrounding bone: subsequently, several surgical procedures may often be necessary to complete the therapy. This increases the treatment cost substantially, prosthesis delivery is delayed, and patient acceptance of treatment plan is decreased. In these cases, implant relocation with segmental osteotomies can be an alternative approach to meet patient's requirements for a less invasive and time-consuming treatment, permitting recovery of the malpositioned fixture to function and esthetics in a single-stage surgery.

However, no reports exist providing long-term data relating the status of malposed osseointegrated implants that have been moved to a more favorable prosthetic position with segmental osteotomies. This retrospective clinical study, involving five different centers, provides the first 1- to 15-year results on implants relocated in a single-stage surgery, with slightly different surgical techniques. The main operative differences between the cases in this study relate to the osteotomic technique (burs, saws, or piezoelectric device), the type of fixation (anchored to the bone or to adjacent teeth or implants), the choice of grafting biomaterials, and the duration of the healing period. The similarities between the cases include preservation of the palatal or lingual vascular supply by elevating surgical flaps on the buccal aspect only, careful preparation of the osteotomies to obtain fine cuts with minimal generation of heat, care to avoid damage to adjacent natural teeth, and rigid fixation of the translated bone block.

In our retrospective study, a point-by-point comparative analysis between all the surgical variables was impossible due to the small number of surgical sites considered and the nonhomogenous degree of translational and/or rotational movement applied to the bone-implant block in the different situations. Nevertheless, no variations were found regarding the implant survival rate (100%) between the five centers and between the early cases and the late ones, irrespective of the variations in the surgical technique.

All the implants considered in this study were connected to a healing abutment or to a prosthetic restoration at the time of surgery: early marginal bone loss often observed during the first year of function had already occurred in all cases. Consequently, marginal bone resorption observed after relocation procedures can be likely attributed to the surgical trauma and to other contributing factors (biological width, occlusal overload, and peri-implantitis).[35] The DIB radiographic values measured 12 months after surgery reflected a very limited mean marginal bone loss (0.36 mm) around relocated implants. These findings are in line with studies performed in orthodontic and orthognatic surgery,[36,37] which demonstrated no loss of alveolar bone support after segmental osteotomies between natural teeth.

The healing periods between the time of surgical relocation and prosthetic loading were varied. For this reason, no conclusion can be drawn regarding the optimum healing period.

The esthetic improvements were extremely significant in all of the cases when considering both the professional evaluation (PES) and patients' subjective perception ($VRS_{satisfaction}$). The procedure was found to be not excessively invasive (77% of the subjects would undergo this surgery again, if necessary) and the discomfort was acceptable (54% related low or no discomfort). Moreover, as the large majority of our study population was composed of women (93%), in whom implant surgery may be significantly associated with higher anxiety levels and pain than in men,[38–40] it is possible that the negative part of the feedback recorded may be an overestimation when compared with a broader population with gender balance.

Comparing our observations with the existing literature on vascularized bone blocks healing,[41,42] it seems appropriate to stress three main factors that are fundamental in determining the success of implant relocation procedure:

- maximum preservation of blood supply during the early phases of healing;
- minimum gap between the mobilized block and adjacent bone;
- firm and stable bone block fixation.

Flap design, which was always elevated on the facial aspect alone, must preserve as much as possible the vascularization of the mobilized segment: in fact, undisturbed periosteal vessels on the palatal side are the main source of blood supply for the mobilized block before neoangiogenesis and a newly formed vascular network start to restore the hematic circulation interrupted by osteotomies.[43,44]

A minimum gap between the relocated block and the adjacent bone represents another crucial factor in enhancing the velocity and quality of healing: a gap lower than 2 mm is ideal in promoting faster healing with new bone formation.[45,46] Nowadays, the use of a piezoelectric device, whose narrow micrometric cut is very precise and seems also to promote a faster bone healing response when compared with burs and saws,[47–49] could be probably advantageous in this particular application. Moreover, the patients treated in this study with ultrasonic surgery reported significantly less pain and discomfort than patients operated with burs or saws: this is in accordance with recent studies conducted in oral surgery and otorhinolaryngology.[50,51]

Once the relocated block reached the final position, it is necessary to achieve a firm stabilization of the mobilized bone-implant segment. The absence of micromovements is a fundamental element in promoting osseous repair: mobility can result in scar formation, encapsulation, and/or sloughing of the segment.[52,53] From our data, either the fixation of the relocated block to adjacent teeth or implants by means of a rigid appliance and the use of miniplates anchored to the bone seem to be reliable methods in assuring a firm stabilization.

It is important to remark that the encouraging findings of the present study have to be regarded with caution due to the relatively low number of cases in the sample and to the bias present in the selection of the centers (experienced clinicians who even published scientific reports on this specific topic). Risks of significant morbidity in case the vascularization of the bone-implant block was compromised are always present: for this reason, implant relocation technique should be undertaken only by experienced operators after an accurate surgical planning.

CONCLUSIONS

Long-term results coming from this retrospective multicenter case series suggest that implant relocation with segmental osteotomies could be an effective alternative method to correct the position of unserviceable implants in a single-stage surgery, permitting acceptable and long-lasting results in terms of function and esthetics to be obtained. Nevertheless, prospective clinical trials and additional long-term analyses are necessary to confirm encouraging preliminary outcomes coming from this study, especially in terms of safety and predictability.

REFERENCES

1. Hämmerle CH, Chen ST, Wilson TG Jr. Consensus statements and recommended clinical procedures regarding the placement of implants in extraction sockets. Int J Oral Maxillofac Implants 2004; 19:26–28.
2. Chen ST, Buser D. Esthetic complications due to implant malpositions: etiology, prevention, and treatment. In: Froum SJ, ed. Dental implant complications: etiology, prevention, and treatment. Chichester: Wiley-Blackwell, 2010:134–155.
3. Duff RE, Razzoog ME. Management of a partially edentulous patient with malpositioned implants, using all-ceramic abutments and all-ceramic restorations: a clinical report. J Prosthet Dent 2006; 98:309–312.
4. Asvanund C, Morgano SM. Restoration of unfavourably positioned implants for a partially edentulous patient by using an overdenture retained with a milled bar and attachments: a case report. J Prosthet Dent 2004; 37:6–10.
5. Shor A, Shor K, Goto Y. Implant-retained overdenture design for the malpositioned mandibular implants. Compend Contin Educ Dent 2006; 27:411–419.
6. Moeller MS, Duff RE, Razzoog ME. Rehabilitation of malpositioned implants with a CAD/CAM milled implant overdenture: a clinical report. J Prosthet Dent 2011; 105:143–146.
7. Samborski CS. Management of an implant case that required retreatment: a case report. J Oral Implantol 2001; 27:118–122.
8. Fugazzotto PA. Bone regeneration over a poorly-positioned implant to correct an esthetic deformity: a case report. J Periodontol 1993; 64:1088–1091.
9. Bell WH. Biologic basis for maxillary osteotomies. Am J Phys Anthropol 1973; 38:279–289.
10. Burk JL Jr, Provencher RF Jr, McKean TW. Small segmental and unitooth ostectomies to correct dento-alveolar deformities. J Oral Surg 1977; 35:453–460.

11. Epker BN, Paulus PJ. Surgical-orthodontic correction of adult malocclusions: single-tooth dento-osseous osteotomies. Am J Orthod 1978; 74:551–563.
12. Patrikiou AK, Katsavrias EG. Repositioning ankylosed maxillary canines by segmental osteotomy. J Clin Orthod 1995; 29:625–628.
13. Svensson B, Adell R, Swartz B. Correction of implant misalignment by segmental osteotomy: a case report. Int J Oral Maxillofac Implants 1993; 8:459–463.
14. Martin RJ, Goupil MT, Goldschmidt M. Single-implant segmental osteotomy: a case report. Int J Oral Maxillofac Implants 1998; 13:710–712.
15. Guerrero CA, Laplana R, Figueredo N, Rojas A. Surgical implant repositioning: a clinical report. Int J Oral Maxillofac Implants 1999; 14:48–54.
16. Warden PJ, Scuba JR. Surgical repositioning of a malposed, unserviceable implant: case report. J Oral Maxillofac Surg 2000; 58:433–435.
17. Storum K, Carrick JL. Implant-osseous osteotomy for correction of the misaligned anterior maxillary implant. Dent Clin North Am 2001; 45:181–187.
18. Poggio CE, Salvato A. Implant repositioning for esthetic reasons: a clinical report. J Prosthet Dent 2001; 86:126–129.
19. Kassolis JD, Baer ML, Reynolds MA. The segmental osteotomy in the management of malposed implants: a case report and literature review. J Periodontol 2003; 74:529–536.
20. Raghoebar GM, Visser A, Vissink A. Correction of a malpositioned endosseous implant by a segmental osteotomy: a case report. Int J Oral Maxillofac Implants 2005; 20:627–631.
21. Stacchi C, Costantinides F, Biasotto M, Di Lenarda R. Relocation of a malpositioned maxillary implant with piezoelectric osteotomies: a case report. Int J Periodontics Restorative Dent 2008; 28:489–495.
22. Chen ST, Callis S. Mucosal recession following immediate implant placement in a maxillary lateral incisor site. In: Chen ST, Buser D, eds. Iti treatment guide. Vol. 3. Berlin: Quintessence Publishing, 2008:185–190.
23. Rosen D. Repositioning malposed implants: report of two cases. Implant Dent 2010; 19:184–188.
24. Stacchi C, Bonino M, Di Lenarda R. Surgical relocation of a malpositioned, unserviceable implant protruding into the maxillary sinus cavity. A clinical report. J Oral Implantol 2010. DOI: http://dx.doi.org/10.1563/AAID-JOI-D-10-00107.
25. Zechner W, Bernhart T, Zauza K, Celar A, Watzek G. Multidimensional osteodistraction for correction of implant malposition in edentulous segments. Clin Oral Implants Res 2001; 12:531–538.
26. Gotta S, Sarnachiaro GO, Tarnow DP. Distraction osteogenesis and orthodontic therapy in the treatment of malpositioned osseointegrated implants: a case report. Pract Proced Aesthet Dent 2008; 20:401–405.
27. Ueki K, Marukawa K, Okabe K, et al. Esthetic improvement using conventional orthodontic devices after segmental osteotomy in treatment of malpositioned implants. J Oral Maxillofac Surg 2011; 69:939–943.
28. Oduncuoglu BF, Alaaddinoglu EE, Oguz Y, Uckan S, Erkut S. Repositioning a prosthetically unfavorable implant by vertical distraction osteogenesis. J Oral Maxillofac Surg 2011; 69:1628–1632.
29. Fürhauser R, Florescu D, Benesch T, Haas R, Mailath G, Watzek G. Evaluation of soft tissue around single tooth implant crowns: the pink esthetic score. Clin Oral Implants Res 2005; 16:639–644.
30. Albrektsson T, Zarb G, Worthington P, Eriksson B. Long term efficacy of currently used dental implants: a review and proposed criteria of implant success. Int J Oral Maxillofac Implants 1986; 1:11–25.
31. Buser D, Weber HP, Brägger U, Balsiger C. Tissue integration of one-stage ITI implants. 3-year results of a longitudinal study with Hollow-Cylinder and Hollow-Screw implants. Int J Oral Maxillofac Implants 1991; 6:405–412.
32. Weber H, Buser D, Fiorellini JP, Williams R. Radiographic evaluation of crestal bone levels adjacent to nonsubmerged titanium implants. Clin Oral Implants Res 1992; 3:181–188.
33. Chen ST, Darby IB, Reynolds EC. A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. Clin Oral Implants Res 2007; 18:552–562.
34. Buser D, Chen ST, Weber HP, Belser UC. Early implant placement following single-tooth extraction in the esthetic zone: biologic rationale and surgical procedures. Int J Periodontics Restorative Dent 2008; 28:441–451.
35. Oh TJ, Yoon J, Misch CE, Wang HL. The causes of early implant bone loss: myth or science? J Periodontol 2002; 73:322–333.
36. Fox ME, Stephens WF, Wolford LM, el Deeb M. Effects of interdental osteotomies on the periodontal and osseous supporting tissues. Int J Adult Orthodon Orthognath Surg 1991; 6:39–46.
37. Morgan TA, Fridrich KL. Effects of the multiple-piece maxillary osteotomy on the periodontium. Int J Adult Orthodon Orthognath Surg 2001; 16:255–265.
38. Unruh AM. Gender variations in clinical pain experience. Pain 1996; 65:123–167.
39. Eli I, Schwartz-Arad D, Baht R, Ben-Tuvim H. Effect of anxiety on the experience of pain in implant insertion. Clin Oral Implants Res 2003; 14:115–118.
40. Al-Khabbaz AK, Griffin TJ, Al-Shammari KF. Assessment of pain associated with the surgical placement of dental implants. J Periodontol 2007; 78:239–246.
41. Bieber EJ, Wood MB. Bone reconstruction. Clin Plast Surg 1986; 13:645–655.
42. Hierner R, Täger G, Nast-Kolb D. Vascularized bone transfer. Unfallchirurg 2009; 112:405–416.

43. Bell WH, Schendel SA, Finn R. Revascularization after surgical repositioning of one-tooth dento-osseous segments. J Oral Surg 1978; 36:757–765.
44. Boc T, Peterson L. Revascularization after posterior mandibular alveolar osteotomy. J Oral Surg 1981; 39:177–181.
45. Alberius P, Gordh M, Lindberg L, Johnell O. Influence of surrounding soft tissues on onlay bone graft incorporation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996; 82:22–33.
46. Gordh M, Alberius P. Some basic factors essential to autogeneic nonvascularized onlay bone grafting to the craniofacial skeleton. Scand J Plast Reconstr Surg Hand Surg 1999; 33:129–146.
47. Vercellotti T, Nevins ML, Kim DM, et al. Osseous response following resective therapy with piezosurgery. Int J Periodontics Restorative Dent 2005; 25:543–549.
48. Preti G, Martinasso G, Peirone B, et al. Cytokines and growth factors involved in the osseointegration of oral titanium implants positioned using piezoelectric bone surgery versus a drill technique: a pilot study in minipigs. J Periodontol 2007; 78:716–722.
49. Stacchi C, Vercellotti T, Torelli L, Furlan F, Di Lenarda R. Changes in implant stability using different site preparation techniques: twist drills versus piezosurgery. A single-blinded, randomized, controlled clinical trial. Clin Implant Dent Relat Res 2011. DOI: 10.1111/j.1708-8208.2011.00341.x.
50. Sortino F, Pedullà E, Masoli V. The piezoelectric and rotatory osteotomy technique in impacted third molar surgery: comparison of postoperative recovery. J Oral Maxillofac Surg 2008; 66:2444–2448.
51. Crippa B, Salzano FA, Mora R, Dellepiane M, Salami A, Guastini L. Comparison of postoperative pain: piezoelectric device versus microdrill. Eur Arch Otorhinolaryngol 2011; 268:1279–1282.
52. Bays RA. Rigid stabilization system for maxillary osteotomies. J Oral Maxillofac Surg 1985; 43:60–63.
53. Johnson EE, Urist MR, Finerman GA. Distal metaphyseal tibial non-union. Deformity and bone loss treated by open reduction, internal fixation, and human bone morphogenetic protein (hBMP). Clin Orthop Relat Res 1990; 250:234–240.