Implant stability evaluation by resonance frequency analysis in the fit lock technique. A clinical study

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Summary

Surgical procedures for the application of implants in the lateral-superior sectors are affected by the availability of the residual bone.
When this condition is lower than 5 mm it is recommended that techniques involving two therapeutic phases, a reconstructive and an applicative one, as reported in the international literature, are adopted.
The authors propose here a new method with the potential to apply implants simultaneously with the reconstructive phase.
The aim of this longitudinal retrospective study was to evaluate the stability of implants applied with the fit lock technique in the upper maxillarys in us with bone availability lower than 4 mm by measuring resonance frequency at different follow-up periods
The seme as urements, carried out on 30 implants, were analysed with specific statistical procedures.
The results indicate that the stability of the implants inserted with the fit lock method increases progressively over time in a statistically significant manner. The stability recorded after one year from the insertion (ISQ T2) is significantly higher than that recorded after six months (ISQ T1), and this is significantly higher than that recorded at the time of implant placement (ISQ T0).
The implants inserted in the maxillary zones with scarce bone availability and applied with this technique showed a similar stability as reported with other techniques.
In light of the results, the authors confirm that the primary stability represents the basic requirement to guarantee a correct healing of the implant and demonstrate that the fit lock technique also all ows reaching this condition when bone availability is minimal.

Key word: resonance frequency analysis, bone grafting, dental implants.

Introduction

The pneumatization of the sinus is a frequently occurring phenomenon in absence of dental elements, causing a vertical reduction of bone availability and limiting the implant placement for prosthetic rehabilitation (1). The approach strategy to this anatomical zone has always been debated, both in the case of a surgical approach and concerning the possible post-surgical complications (2-5).
From the international literature, it is clear that in cases where bone availability is less than 4 mm, as in the classification IV of Misch, a first reconstructive-regenerative phase is indispensable, followed by a second surgical phase for the implant placement (6, 7). This should be done with the goal of implant primary stability, which according to long term studies have a success similar to the implants inserted in normal bone conditions (8).
Some authors consider the possibility of placing the implants at the same surgical time by using extra-oral autologous bone graft (from hip or fibula) in order to obtain the primary stabilization (9). Other authors (Vollmer, Lang, Engelke) proposed resorbable plaques from extrasinus osteosynthesis, but not for the primary implant stability (10-12).
However, as reported by some authors, the survival is also affected by the quality and density of the bone, which is reduced in these zones and thereby can affect the stability (13, 14).
The authors have proposed the fit lock technique, which allows the implants to be placed simultaneously with residual bone thickness less than 4 mm, while harvesting intraoral autologous bone (15). Given the long term results, a longitudinal study has been conducted on 11 patients treated with this technique while using a new implant design to guarantee better stability of the graft also in cases of insufficient bone density.
The aim of the study, retrospective and longitudinal, is to evaluate by resonance frequency across the follow-

up periods the degree of the stability of the implants applied with the fit lock technique in the upper sinus with bone availability lower than 4 mm. The stability measurement has been carried out by resonance frequency analysis with Osstel Mentor (Osstell instrument, Integration Diagnostics AB, Gothenburg, Sweden) (16-20).
The Tekka implants underwent measures of resonance frequency at the time of the initial placement, six months, and 12 months after progressive load to evaluate the degree of osteointegration; moreover, radiographic TC dentalscan and Orthopanoramic RX were carried out both at the diagnosis time and following treatment.

Materials and methods

About 50 patients were visited between January 2011 and January 2012 for implant-supported rehabilitation of the posterior-superior sectors at the Municipal Japanese University Hospital of Santa Cruz de la Sierra, Bolivia and at the Department of Odontostomatologic Sciences, Sapienza University of Rome.
All patients were studied following our clinical-implantologic protocol for prosthetic rehabilitation. During this period 11 patients were selected according to the following exclusion and inclusion criteria.
Exclusion criteria:

- Low oral hygiene,
- Acute or chronic synusitis of the maxillary sinus,
- Patients with high risk factors,
- Patients under Cadwell Luc treatments,
- Patients under radiotherapy,
- Patients with a bone height above ≥ 4 mm.
- Inclusion criteria:
- Bone height ≤ 4 mm (X-ray assessment),
- Bone availability for harvesting at the ramus-symphysis donor site,
- Patient's consent to participate in the clinical study,
- Patient's consent to undergo regular clinical follow-up.

From the initial 50 patients 15 were excluded, 20 did not give consent, 4 did not undergo the follow-up. The remaining sample consisted of 11 patients.
This final sample was composed by 6 men, mean age 58.2, and 5 women, mean age 59.8. In total there were 15 sinus elevations and 30 implant placements.
All patients where treated with Tekka grade 5 titanium implants, with a half-conical full screw shape, double progressive condensing thread, SA2 surface (sandblasted and double acid etch) that consists in sandblasting trough corundum micro beads of 260 micron diameter, followed by a double chemical treatment with acid tipping.
The allocation of the 30 implants was as follows: 2 in area 14; 2 in area 15; 6 in area 16; 5 in area 17; 1 in area 24; 2 in area 25; 7 in area 26; 5 in area 27. All implants were of 11.5 lenght and 4.0 mm diameter (Tab. 1).
The implantology surgical protocol is the same described in a previous article by the authors, although the operators were not always the same (Figs. 1-13).
The Tekka implants were evaluated with measures of resonance frequency during the follow-up periods using Osstell Mentor (Osstell instrument, Integration Diagnostics AB, Gothenburg, Sweden) at time 0 (T0) of implant placement, after 6 months (T1), and after 12 months (T2), upon progressive load.
The recordings were carried out with double directional measurement (vestibular oral or oro vestibular and mesiodistal or disto-mesial) on the Smart Peg (Type 49) as reported by the company indications, and the value reported in Table 1 is the arithmetic mean of the two (21, 22).

Statistical analysis

- Normality test on the distribution of the stability values (Kolmogorov-Smirnov test, Lilliefors test, Shapiro-Wilk test). Diagrams a-b-c.
- Descriptive statistics of the stability values: mean, median, mode, variance, standard deviation standard error, quartiles) Diagram d.
- Non parametric analysis of variance (Friedman ANOVA). Diagram e.
- *Post hoc* tests.

Aim: to verify if the implant stability, measured by "implant stability quotient" (ISQ), increases progressively, and in a statistically significant manner, from the moment of the placement (ISQ T0) up to six months (ISQ T1) and one year (ISQ T2).

Results

The overall results reported in Table 1 show the loss of only two implants in position 24 and 27 on the same patient, due to a post-surgical infection occurring 15 days after placement.
No complications occurred for the remaining 18 implants across the study period.
The evaluation of the data across the three follow-up periods showed a distribution that significantly deviated from normality. From the graphs it can be seen that two of the selected variables (ISQ T0 and ISQ T1) have a skewed distribution, although the deviation from normality is statistically significant depending on the test (Diagrams a-b-c).
The Friedman non parametric test showed that implant stability (mean and median values) progressively increased over time; ISQ T2 is higher than ISQ T1, and this latter is higher than ISQ T0 (Diagram d).
The differences were statistically significant (Diagrams e-f).
Moreover, the post-hoc tests for the three possible comparisons showed the following results: for ISQ T0 vs ISQ T1, z = 3.408; for ISQ T0 vs ISQ T2, z = 7.016; for ISQ T1 vs ISQ T2, z = 3.608; critical Z = 2.394. The critical value for significance was always passed.

Discussion and Conclusions

In literature the implant survival in posterior lateral areas (type SA4) - ranges between 90 and 97%.

Table 1. Specimen description.

Patient	Age	Sex	Implant side	Implant misure H Ø	ISQ T0	ISQ T1	ISQ T2
1	63	F	14	11,5 4	52	52	64
			16	11,5 4	49	54	66
			17	11,5 4	51	52	71
2	58	F	16	11,5 4	42	48	63
3	64	M	25	11,5 4	53	59	67
			26	11,5 4	54	55	64
4	59	M	26	11,5 4	38	48	66
			27	11,5 4	42	49	64
			16	11,5 4	55	56	68
			17	11,5 4	51	51	66
5	57	F	27	11,5 4	55	56	71
6	52	M	25	11,5 4	36	49	59
			26	11,5 4	41	49	58
7	55	M	16	11,5 4	44	49	67
			17	11,5 4	41	48	68
8	50	F	15	11,5 4	42	51	65
			17	11,5 4	46	53	62
			26	11,5 4	44	52	61
			27	11,5 4	32	43	67
9	49	M	14	11,5 4	53	62	62
			15	11,5 4	52	63	63
			16	11,5 4	55	71	71
			24	11,5 4	27	0	0
			26	11,5 4	39	47	59
			27	11,5 4	30	0	0
10	51	M	26	11,5 4	61	61	71
			27	11,5 4	52	55	69
			16	11,5 4	55	55	66
			17	11,5 4	41	49	59
11	50	F	26	11,5 4	44	49	58

These data are influenced by several factors (Del Fabbro, 2004):

- for example, the survival of the only autologous bone is about 87.70%, while in combination with bone substitutes is about 94.88% and when only bone substitutes are used the survival is about 95.98%;
- implant production methodology - the survival of non treated implants is about 85.6%, while the percentage rises to 95.8% if implants are treated superficially and made rough ones;
- timing of the insertion - the implant can be applied in the same surgical procedure (one-stage surgery) or when the regeneration is complete: in first case the survival rate is 92.17%, while in the second case is 92.93% (23).

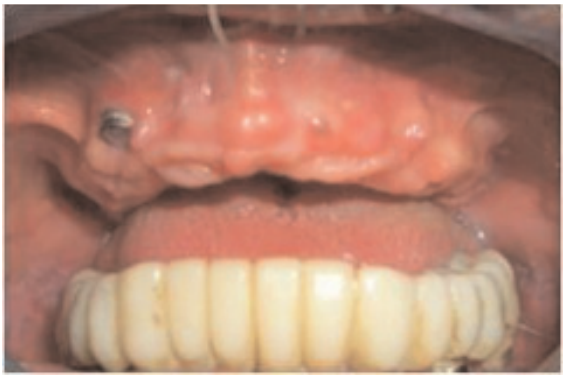


Figure 1. Pre-surgical intraoral view of the patient.

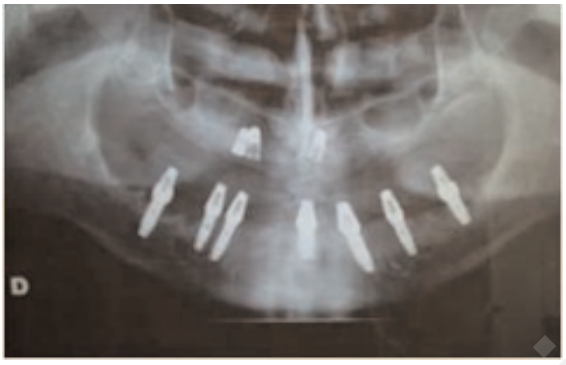


Figure 2. Pre-surgical orthopanoramic X-ray.

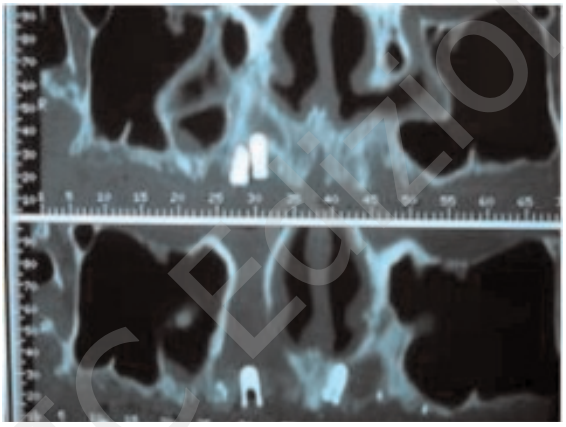


Figure 3. Pre-surgical Tc Panorex.

Some surgical protocols suggest that, if the bone available is thinner than 4 mm, as in Misch IV classification, first is necessary a reconstructive-regenerative phase and then a second surgical phase of implant insertion (6, 7). These protocols are justified by the fact that, as reported by the authors, the survival of the implant is also influenced by the quality and density of the bone which is reduced in these areas (13, 14). Nedir et al, in 2009, proposed one-stage surgery with simultaneous insertion of implants in patients with atrophic maxilla without grafting, provided that primary stability was guaranteed (24). Later other authors have proposed, in

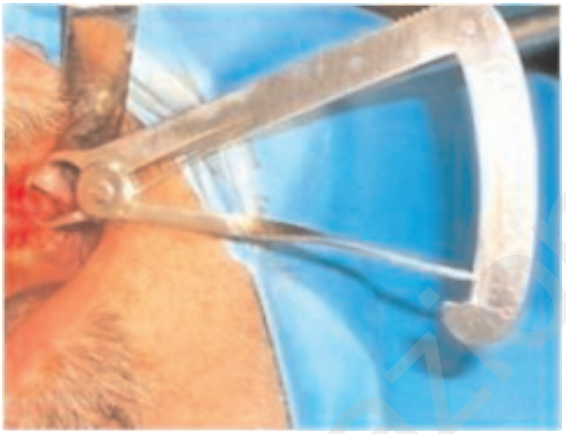


Figure 4. Intrasurgical measurement with caliper for residual bone evaluation.

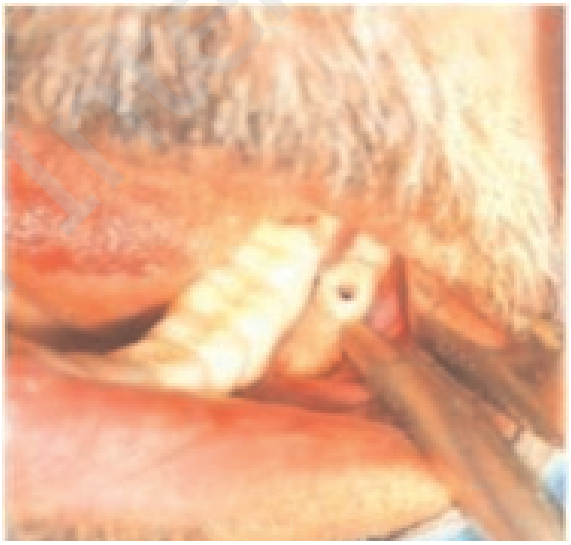


Figure 5. Sampling of the inlay bone from the mandibular ramus.

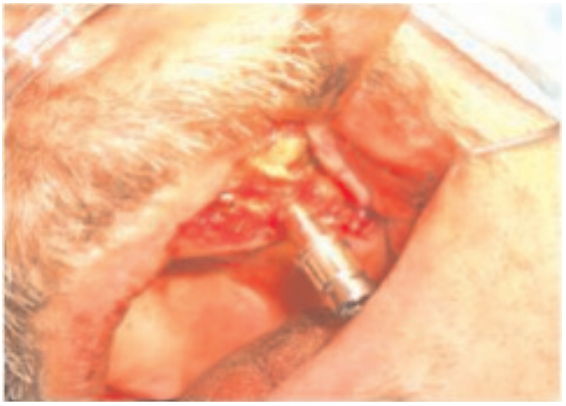


Figure 6. Placement and stabilization of the implant with the inlay bone.

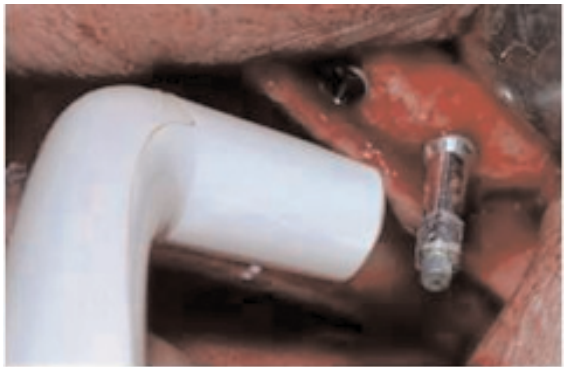
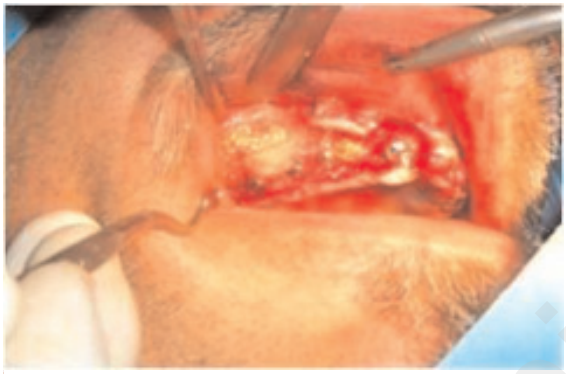
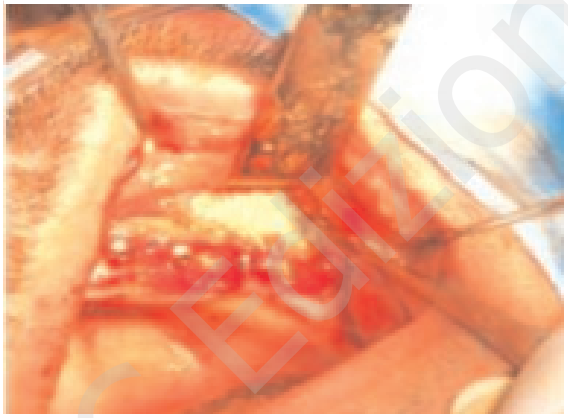


Figure 7. Analysis of implant stability with ostellmentor in surgical phase.





Figures 8 and 9. Filling with heterologous bone of the residual spaces of the maxillary sinus.

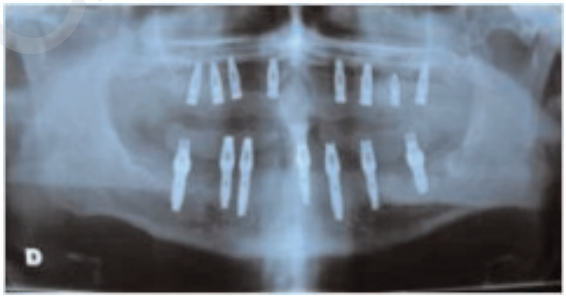


Figure 10. Post-surgical orthopanoramic X-ray.

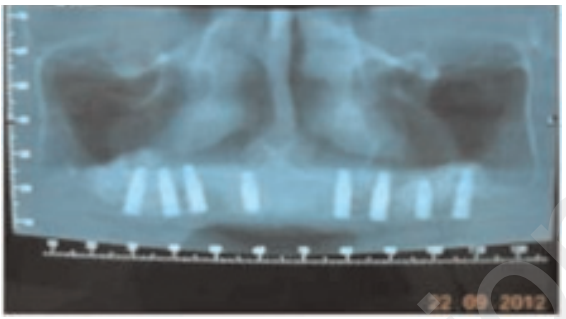


Figure 11. Tc Panorex control.

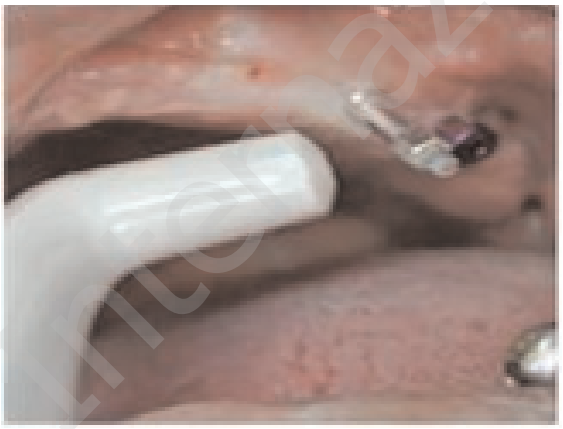


Figure 12. Analysis of implant stability with ostellmentor at the time of application of the healing screws.

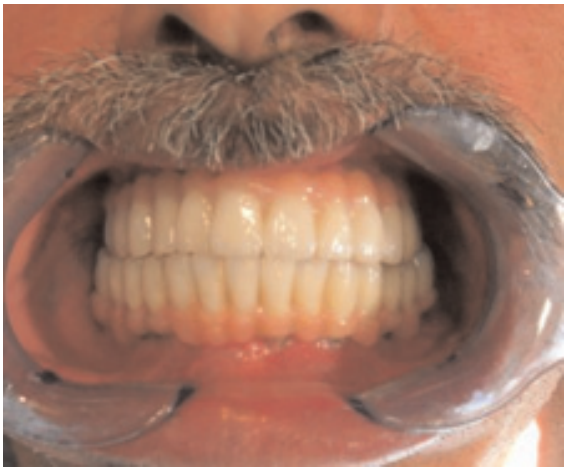
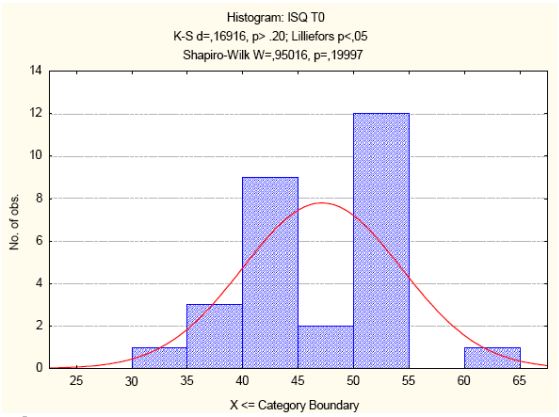


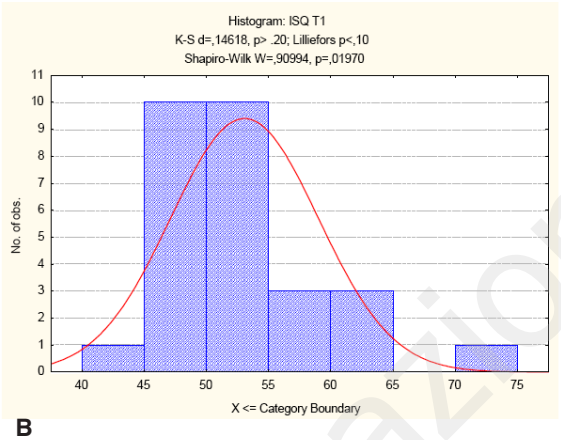
Figure 13. Provisional prosthesis.

a wider caseload, the contextual placement of the implant without filling or with PRF (platelet-rich fibrin), reporting a 100% of success also in cases of lower bone availability (25, 26).

The described technique seems to ensure a good success rate in cases of Misch IV class with contextual implant placement, with a success percentage of 93.4% one year after placement. The technique allows an immediate stabilization of the implants also due to the new design that improves performance in those cases



A



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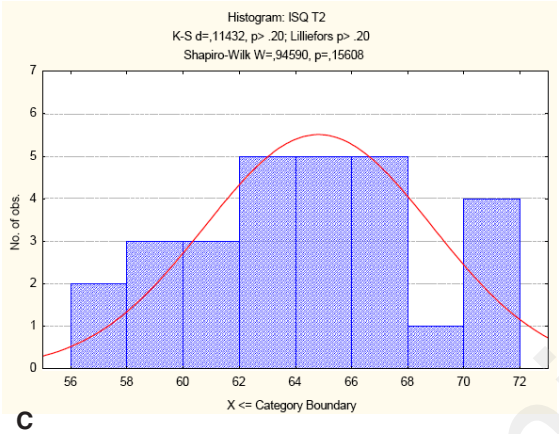

C

Diagrams a-b-c. Frequency distribution of implant stability values (ISQ) and outcome of the normality tests (Kolmogorov-Smirnov, Lilliefors, Shapiro-Wilk) at time T0 (a), T1 (b), and T2 (c). See "Materials and Methods" section for details.

	Descriptive Statistics (StatisticaFalisi)												
Variable	Valid N	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower Quartile	Upper Quartile	Variance	Std.Dev.	Coef.Var.	Standard Error
ISQ T0	28	47,14286	47,50000	55,00000	4	32,00000	61,00000	41,50000	53,00000	51,31217	7,163251	15,19478	1,353727

	Descriptive Statistics (StatisticaFalisi)												
Variable	Valid N	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower Quartile	Upper Quartile	Variance	Std.Dev.	Coef.Var.	Standard Error
ISQ T1	28	53,07143	52,00000	49,00000	6	43,00000	71,00000	49,00000	55,50000	35,32804	5,943740	11,19951	1,123261

	Descriptive Statistics (StatisticaFalisi)												
Variable	Valid N	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower Quartile	Upper Quartile	Variance	Std.Dev.	Coef.Var.	Standard Error
ISQ T2	28	64,82143	65,50000	Multiple	4	58,00000	71,00000	62,00000	67,50000	16,44841	4,055664	6,256672	0,766449

Table 2. Descriptive statistics of implant stability values (ISQ) at time T0, T1, and T2. The ISQ values (mean and median) progressively increase over time (see also diagram f).

	Friedman ANOVA and Kendall Coeff. of Concordance (StatisticaFalisi) ANOVA Chi Sqr. (N = 28, df = 2) = 52,51429 p = ,00000 Coeff. of Concordance = ,93776 Aver. rank r = ,93545			
Variable	Average Rank	Sum of Ranks	Mean	Std.Dev.
ISQ T0	1,071429	30,00000	47,14286	7,163251
ISQ T1	1,982143	55,50000	53,07143	5,943740
ISQ T2	2,946429	82,50000	64,82143	4,055664

Diagram e. Outcome of the Friedman ANOVA test indicating the overall significance of the time effect.

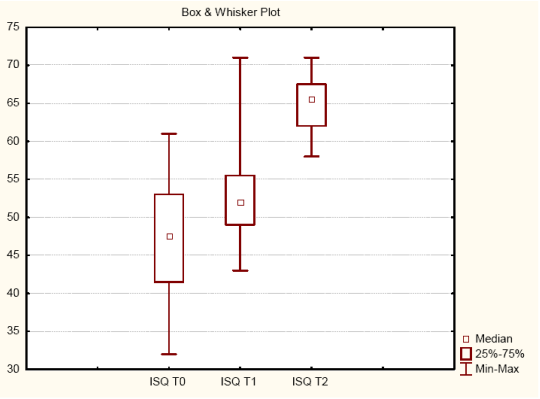

Diagram f. Temporal profile of the ISQ values at T0, T1, T2. The small centered squares are medians, the boxes indicate the highest and the lowest quartiles, the vertical bars indicate minimum and maximum values.

with reduced bone density. Compared to similar techniques it appears simpler and reproducible, it does not depend on the operator and allows a lower biological and economic effort for the patient, considerably reducing the time of prosthetic rehabilitation.

The results suggest that the stability of the implants applied with the fit lock technique increases progressively over time in a significant manner.

The implant stability one year after placement (ISQ T2) is significantly higher than the stability recorded after six months (ISQ T1), and this latter score is higher than the stability recorded at the beginning (ISQ T0), as evident from the post hoc tests. The ISQ value is in line with other studies concerning reliability, allowing a delayed loading of the implants, and compatibly with the biological times (27, 28).

The main disadvantage, as already published, is the impossibility of using implants with a diameter higher than 4 mm, since the graft diameter also can't be more than 8 mm due to anatomical limitations of the antrum, or when for reasons of dental-implant discrepancy, an only graft is required.

This method certainly represents a therapeutic alternative, given the clinical results are comparable to other techniques described in the literature (29, 30).

In light of these results, the authors confirm that the primary stability represents the basic requirement to guarantee a correct healing of the implant and show that the fit lock technique also allows reaching this state in conditions of lower bone availability.

Because of the low sample size, these results need to be complemented by an istomorphometric analysis and the use of more patients, although to date they represent, together with the previous report, the main published clinical records.

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References

1. Razavi R, Zena RB, Khan Z, Gould AR. Anatomic site evaluation of edentulous maxillae for dental implant placement. J Prosthodont 1995 Jun; 4(2):90-94.
2. Jung JH, Choi BH, Jeong SM, Li J, Lee SH, Lee HJ. A retrospective study of the effects on sinus complications of exposing dental implants to the maxillary sinus cavity. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007 May; 103(5):623-625. E pub 2007 Jan 25.
3. Doud Galli SK, Lebowitz RA, Giacchi RJ, Glickman R, Jacobs JB. Chronic sinusitis complicating sinus lift surgery. Am J Rhinol 2001; 15:181-186.
4. McDermott NE, Chuang SK, Woo VV, Dodson TB. Maxillary sinus augmentation as a risk factor for implant failure. Int J Oral Maxillofac Implants 2006; 21:366-374.
5. Li J, Wang HL. Common implant-related advanced bone grafting complications: classification, etiology, and management. Implant Dent 2008 Dec; 17(4):389-401. doi: 10.1097/ID.0b013e31818c4992. Review.
6. Misch CE. Maxillary sinus augmentation for endosteal implants: organized alternative treatment plans. Int J Oral Implantol 1987; 4:49-58.
7. Tischler M, Misch CE. Extraction site bone grafting in generaldentistry. Review of applications and principles. Dent-Today 2004; 23:108-113.
8. Georgescu CE, Rusu MC, Sandulescu M, Enache AM, Didilescu AC. Quantitative and qualitative bone analysis in the maxillary lateral region. Surg Radiol Anat 2012 Aug; 34(6):551-8. doi: 10.1007/s00276-012-0955-6. E pub 2012 Mar 22.
9. Blomquist je et al. Retrospective analysis of one stage maxillary sinus augmentation with end osseous implants. Int J oral maxillofac implants 1996; 11:512-21.
10. Wollmer R et al. Sinus elevation and siglestage surgical implant placement with a titanium ostheosyntesis bar. Pract Proced Aesthet Dent 2002; 14:307-311.
11. Lang M. Der Sinus-Implantat-Stabilisator in Extremfällen. Implantologie J 1999; 3:27-30.
12. Lindorf HH, Müller-Herzog R. Der autologe Sinus-Implantat-Stabilisator (ASIS). ZMK 2004; 4:180-189.
13. Jaffin RA, Berman CL. Theexessive loss of Branemark Fixture in tipe IV bone. 5 year analysis. J Periodontol 1991; 62:2-4.
14. Turkyilmaz I, McGlumphy EA. Influence of bone density on implant stability parameters and implant success: a retrospective clinical study. BMC Oral Health. 2008 Nov 24; 8:32. doi: 10.1186/1472-6831-8-32.
15. Vittorini Velasquez P et al. Self-bone graft and simultaneous application of implants in the upper jawbone. (Fit lock technique) Acta Odontol. Latinoam. 2011 Vol. 24; 2:163-167.
16. Fuster-Torres MÁ, Peñarrocha-Diago M, Peñarrocha-Oltra D, Peñarrocha-Diago M. Relationships between bone density values from cone beam computed tomography, maximum insertion torque, and resonance frequency analysis at implant placement: a pilot study. Int J Oral Maxillofac Implants 2011 Sep-Oct; 26(5):1051-1056.
17. Cassetta M, Ricci L, Iezzi G, Dell'Aquila D, Piattelli A, PerrottiV. Resonance frequency analysis of implants inserted with a simultaneous grafting procedure: a 5-year follow-up study in man. Int J Periodontics Restorative Dent 2012 Oct; 32(5):581-589.
18. Scarano A, Degidi M, Iezzi G, Petrone G, Piattelli A. Correlation between implant stability quotient and bone-implant contact: a retrospective histological and histomorphometri-

cal study of seven titanium implants retrieved from humans. Clin Implant Dent Relat Res 2006; 8(4):218-222.
19. Nkenke E, Lehner B, Fenner M, Roman FS, Thams U, Neukam FW, Radespiel-Tröger M. Immediate versus delayed loading of dental implants in the maxillae of minipigs: follow-up of implant stability and implant failures. Int J Oral Maxillofac Implants 2005 Jan-Feb; 20(1):39-47.
20. Park JC, Kim HD, Kim SM, Kim MJ, Lee JH. A comparison of implant stability quotients measured using magnetic resonance frequency analysis from two directions: a prospective clinical study during the initial healing period. Clin Oral Implants Res 2010 Jun; 21(6):591-597. doi: 10.1111/j.1600-0501.2009.01868.x. E pub 2010 Feb 1.
21. Gupta RK, PadmanabhanTV. Resonance frequency analysis. Indian J Dent Res 2011 Jul-Aug; 22(4):567-573. doi: 10.4103/0970-9290.90300. Review
22. Nedir R, Bischof M, Szmukler-Moncler S, Bernard J-P, Samson J. Predicting osseointegration by means of implant primary stability. Clin Oral Implants Res 2004Oct; 15(5):520-528.
23. Del Fabbro M, Testori T, Francetti L, Weinstein R. Systematic review of survival rates for implants placed in the grafted maxillary sinus. Int J Periodontics Restorative Dent 2004 Dec; 24(6):565-577.
24. Nedir R, Nurdin N, Szmukler-Moncler S, Bischof M. Osteotome sinus floor elevation technique with out grafting material and immediate implant placement in atrophic posterior maxilla: report of 2 cases. J Oral Maxillofac Surg 2009 May; 67(5):1098-103.
25. Tajima N, Ohba S, Sawase T, Asahina I. Evaluation of sinus floor augmentation with simultaneous implant placement using platelet-rich fibrin as sole grafting material. Int J Oral Maxillofac Implants 2013 Jan-Feb; 28(1):77-83.
26. Rajkumar GC, Aher V, Ramaiya S, Manjunath GS, Kumar DV. Implant placement in the atrophic posterior maxilla with sinus elevation without bone grafting: a 2-year prospective study. Int J Oral Maxillofac Implants 2013 Mar-Apr; 28(2):526-30.
27. Hirsch JM, Ericsson I. Maxillary sinus augmentation using mandibular bone graft and simultaneous installation of implants. Clin Oral implants Res 1991; 2:91-6.
28. Khoury F. Augmentation of sinus floor with mandibular bone block and simultaneous implantation: 6 year clinical investigation. Int J Oral Maxillofac Implants 1999; 14:557-64.
29. Chaushu G, Mardinger O, Calderon S, Moses O, Nissan J. The use of cancellous block allograft for sinus floor augmentation with simultaneous implant placement in the posterior atrophic maxilla. J Periodontol 2009 Mar; 80(3):422-8.
30. Mardinger O, Nissan J, Chaushu G. Sinus floor augmentation with simultaneous implant placement in the severely atrophic maxilla: technical problems and complications. J Periodontol 2007 Oct; 78(10):1872-7.