Prospective Study

The primary stability and survival rate of 2-stage, concial compression screw implants

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Abstract: *The purpose of this study is to report on the initial stability and success rate of STO® implants (Fig. 1) placed in different bone qualities and quantities. The study was performed from March 2004 to August 2006, 76 consecutive patients (57% male) receiving 220 STO® implants (mean = 3.1 per person) were enrolled in this study. The mean age of implant surgery was 49.6 years (age range of 19 to 69 years). Patients were followed for an average of 24.3 months. All implants were 4.1 mm in diameter, with a mean screw length of 10.6 mm. The bone quality at each implant site was categorized as D1-Bone (7%), D2-Bone (70%), D3-Bone (19%), and D4-bone (4%). The mean insertion torque was 48.3 Newtons. Five implants failed during the follow-up period giving an overall survival rate of nearly 98%. Similar rates of survival occurred in patients with (97.9%) and without (97.6%) bone graft (p=0.88). In the maxilla the survival rate was 97.6% and 97.9%; p=0.88 in mandible. Survival rates decreased slightly from the lowest insertion torque category to the highest category (p=0.19). The length of the screw was not significantly associated with failure (p=0.99). There were no statistically significant differences in survival rates by graft type or graft harvest location (p=0.97 and 0.94, respectively). The clinical application of the STO® implant allows successful insertion of artificial abutments for crown and bridge with high torque forces, even in bone with low quality and density or in grafted areas.*

Keywords: *Dental implants, primary stability, insertion torque force, poor bone quality and bone graft.*

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Introduction

Primary stability is a prerequisite for successful osseointegration of crestal implants because movements of 100 Angstrøm or more against the bone may lead to fibrous encapsulation and implant failure.[1,2] Primary stability of the implant during installation of the fixture is important for implant success; however, achieving primary stability is often difficult because the mineralization of the bone may require a treatment protocol, which is adjusted by the surgeon, and based on information gained by the surgeon's tactile sense. Moreover, factors such as tapered design, surface treatment, length and width of the implant fixture, and the shape and numbers of the threads may influence the initial stability.[3] For example, it is conceivable that a tapered or conical implant could have advantages to a cylinder type of implant with respect to primary stability because the tapered fixture continuously condenses the lateral bony wall of the slightly undersized socket during implant installation. In addition to the shape of the implant, effective threads are necessary for reaching the desired implant stability by transforming insertion torque into compression.

This implant penetrates to the apical and lateral direction easily without stopping during implant installation. In doing so, it is possible to obtain high initial torque forces and stability with these implants. The aim of this study is to evaluate the success of the STO® implants under various clinical conditions in natural and augmented bone areas.

Patients and methods

Subjects

In 76 consecutive patients, 220 STO® implants of 4.1 diameter were placed between March 2004 and April 2006. The

implants were equipped with the prosthetic workpieces after a complete mucosal healing period of 3 months in the mandible and 5 months in maxilla. Patient demographics, average length of implants, and the follow up period are described in Table 1.

STO® implants

The STO® implant is a type of 1-stage implant with internal octagon and tapered connection type. Its body is conical and thus similar to the natural root of teeth. The conical design with sharp and deep threads and wide pitched distances of the threads minimizes the quantity of endosseous implant material, thus allowing good blood supply and an easy reinstallation of the internal circulation within the bone. This design provides both apical and lateral compression and condensation which allows for a slightly undersized socket in D2-bone to D4-bone. The compression takes place mainly within the cancellous bone, allowing this part of the bone to contribute to the overall stability immediately after treatment.

Surgical technique

Bone quality was determined by the surgeon's tactile sense during implant site preparation, and classified according to Lekholm and Zarb's.[4] Based on the clinical assessment, various bone grafts were performed for ridge augmentation and/or maxillary sinus floor elevation in patients without enough native bone in the desired implant location. The implant site was selected and drilled initially to an approximate depth of 3-5 mm using a lance drill. The site was then drilled with a 2.2 mm twist drill to the full depth for a selected fixture. The fixture was inserted into the prepared socket using a hand piece with a fixture adaptor. In cases where the fixture stopped in the socket due to resistance from the bone, the fixture adaptor was removed and switched to a manual insertion instrument connected to a torque wrench. Primary stability of the implants was evaluated by the Anthrogyr insertion instrument (Anthrogyr, Sallances, France). The forces for insertion were measured either through the Anthrogyr insertion instrument or through the adjustable torque wrench.

Data Analysis

Descriptive statistics were calculated for baseline variables. The primary outcome of interest was implant failure defined as any reason for removing an implant. Complications, not requiring implant removal, are also reported. Survival rate was determined by dividing the number of implants that did not fail by the total number of implants.

Implant location was categorized as maxilla or mandible. Insertion torque categories were divided into: 7-30N (n=56), 31-50N (n=56), 51-70N (n=45) and +70N (n=63). Screw length categories were divided into: < 10mm (n=79), 10-12mm (n=105), and +12mm (n=36).

Survival rates were stratified by location (maxilla and mandible), bone quality (D1-D4), insertion torque categories, screw length categories, bone graft (yes or no), graft types, graft harvest sites, and timing of graft (delayed or simultaneous) to determine if the risk of failure was related to any particular risk factor. Comparisons were made using the Pearson chi-square ($\div^2$) test. A test for trend was performed when categories were ordered. STATA (Version 9.0, College Station, Texas, United States) was used for the analysis.[5]

Table 1. Patient (N=70) and implant (N=220) characteristics

Characteristics	Mean (SD)	Range
Age (years)	49.6 (10.3)	19 - 69
Follow-up time (months)	24.3 (4.2)	17.8 – 31.6
Implants (per patient)	3.1 (2.0)	1 - 11
Length of implant (mm)	10.6 (2.2)	7 - 29
	N	%
Gender (male)	40	57.1
Follow-up	70	92
Maxilla	125	56.8
Mandible	95	43.2

Table 2. Bone graft characteristics

Characteristics	N	%
Bone graft	95	43.2
Bone graft type*		
Sinus elevation	32	37.7
Inlay graft	15	17.7
Horizontal onlay graft	9	10.6
Vertical onlay graft	9	10.6
Horizontal and vertical onlay graft	7	8.2
Socket elevation	5	5.9
Ridge split	3	3.5
Inlay onlay	2	2.4
Bone graft harvest location		
Ramus (block)	42	44.2
Ramus (plane blade)	20	20.1
Maxillary tuberosity	13	13.5
Bovine bone powder (BBP)	10	10.4
Ramus (particulated)	4	4.2
Iliac bone	3	3.1
Bone graft + BBP	3	3.1
Timing of graft †		
Delayed	30	34.5
Simultaneous	57	65.5

** For the 95 bone grafts. Ten missing values for type of grafting (% based on n=85)*
† For 95 bone grafts. Eight missing values for timing of grafting (% based on n=87)

Table 3. Survival rate by risk factors

	N = 220	%	p-value*
Overall survival	215	97.7	
Bone quality^			0.14
D1 (n=15)	12	80.0	
D2 (n=151)	150	99.3	
D3 (n=42)	42	100	
D4 (n=8)	7	87.5	
Location			
Maxilla (n=125)	122	97.6	0.88
Mandible (n=95)	93	97.9	
Bone graft			0.88
Yes (n=95)	93	97.9	
No (n=125)	122	97.6	
Insertion torque (N)			0.19
7-30 (n=56)	55	98.2	
31-50 (n=56)	56	100	
51-70 (n=45)	44	97.8	
70+ (n=63)	60	95.2	
Screw length (mm)			0.99
< 10 (n=79)	78	98.7	
10-12 (n=105)	101	96.2	
12+ (n=36)	36	100	
Timing of graft			0.30
Delayed (n=30)	30	100	
Simultaneous (n=57)	55	96.5	

**Pearson chi-square test. A test for trend was performed with ordered categories.*
^Totals may not equal 100% do to rounding or missing data.

Results

Patients were followed for an average of 24.3 months (range 17.8-31.6), Table 1. Six patients were lost to follow-up giving a follow-up rate of 92%. There were 125 (56.8%) and 95 (43.2%) implants placed in the maxilla and mandible, respectively, Table 1. All implants were 4.1mm in diameter. The mean screw length was 10.6mm (range 7-29). D1-bone was found in 7% of the sites, D2-bone in 70% of the sites, D3-bone in 19% of the sites, and D4-bone in 4% of the sites. The mean torque force applied to each implant was 48.3N (range 7-70). There was a statistically significant relationship between torque category and bone quality ($p<0.001$). Higher torque forces were applied to patients with higher quality bone. Of the 166 implants placed in higher quality bone (D1 and D2-bone), 104 (62.7%) were inserted with 50N or greater. While in the 50 implants placed in lower quality bone (D3 and D4-bone), only two (4%) were inserted with 50N or greater. Bone grafts were placed in 95 patients (43%), with the most common type being the maxillary sinus floor augmentation, Table 2. Bone graft harvest sites were primarily ramus (44% for block procedures and 20% for plan blade procedures), maxillary tuberosity (14%), and bovine bone powder (BBP) (10%), Table 2. The majority (66%) of the bone grafts were placed simultaneously with the implants, Table 2.

Five implants failed during the observation-up period giving an overall survival rate of 97.7%, Table 3. The failure-type for each implant was asymptomatic loosening. Implant survival was high in the maxilla (97.6%) and mandible (97.9%), $p=0.88$. The lowest survival rates occurred in the highest (D1, 80%) and lowest (D4, 87.5%) qualities of bone; however, this was not statistically significant when tested for trend ($p=0.14$). Similar rates of survival occurred in patients with (97.9%) and without (97.6%) bone graft ($p=0.88$). Survival rates decreased slightly from the lowest insertion torque category to the highest category, however, this was not statistically significant for trend ($p=0.19$). The length of the screw was not significantly associated with failure ($p=0.99$). There were no statistically significant differences in survival rates by graft type or graft harvest location ($p=0.97$ and 0.94, respectively).

Fig 1 : The STO®-Implant provides full compatibility to the 4.8mm ITI-standard. In addition a compression screw bone thread allows aggressive tightening of the implant even in soft bone. The Osmoactive® surface helps to prevent early bacterial colonialization and the same time promotes adhesion of the blood cloth.

Discussion

This study reports on a consecutive series of 76 patients receiving 220 STO® implants with varying degrees of bone quality and quantity. The STO® implant showed high initial torque forces and a high success rate (97.7%) after an average 2 year follow-up period. Failures of the implant were asymptomatic loosening of the implant, occurring in the highest (D1, 80%) and lowest (D4, 87.5%) qualities of bone. Similar rates of survival occurred in patients with and without bone grafts, with different graft types and locations, and between implants placed in the maxilla and mandible.

There are limitations to the present study. Bone quality was assessed through palpation rather than a radiological method. However, the classification of bone quality appeared characteristic of the general population who seeks implant therapy. Torque force insertion was determined using a torque wrench which is simple and

inexpensive; however, torque values measured on different wrenches may vary. In cases where the insertion torque was sufficient to insert the implant to full length, initial stability was measured by the torque values on the Anthogyr implant engine, otherwise, a mechanical torque wrench was used. The main disadvantage was the instrument provided a scale up to 70 Newtons (N); therefore, we were unable to assess values over 70N. However, we were confident that measurements below 70N achieved enough accuracy to determine the effect of torque on outcome.

There are several strengths of this study. Since no patients who presented for implants were excluded, the results are representative of the broad spectrum of patients seen in everyday practice. Specifically, patients who are often turned down due to poor bone quality were treated, as were patients who needed bone graft procedures. Another strength of the study is the follow-up rate of 92%. Finally, the study assessed multiple risk factors in evaluating the success of the STO® implants under various clinical conditions in natural and augmented bone areas.

Research has examined the affect of the implant tapered design and the diameter on the initial stability. Results indicate that the Implant Stability Quotient (ISQ) values of tapered implants were higher than 4.1mm diameter implants and comparable even with implants of 4.8mm diameter.[6] Comparisons have also been made between standard threaded commercially pure titanium implants.[7] These results show that all titanium implants demonstrate good primary stability in the D2-bone and D3-bone, but high primary stability in D4-bone is a result of the higher interfacial stiffness at the implant-bone interface of the tapered implant due to the uninterrupted lateral condensation effect of the bone.[8] The STO® implant consists of a tapered design, but also provides a pointed apex that allows for easy fixture penetration into D4-bone along the prepared socket. During the insertion, the stability of the implant against the bone increases steadily, resulting in relatively high primary stabilities even in D4-bone.

Methods for determining primary stability include Resonance Frequency Analysis (RFA) and recording torque values displayed by implant engines or mechanical torque wrenches. According to Ostman et al., the analysis of primary stability showed higher ISQ values: in men compared with woman, in the mandible compared with the maxilla, in posterior sites compared with anterior sites (especially in the maxilla), and in wide diameter implants compared with regular implants.[9] Also, a correlation exists between bone quality and primary stability, with lower ISQ values obtained for implants placed in softer bone even if the use of a thinner and/or tapered drill cannot compensate for the effect of soft bone.[10] In our report, we assume high values of insertion torque were obtained with the STO® implant because of the extremely tapered and conical body of the implant, combined with the wide, sharp threads. In addition, we inserted the polished part of the neck of the implant which may act as a counterforce without significant contribution to the primary stability.

Intra-oral conditions for implants of these patients varied. Fortunately, to our knowledge, there were no serious underlying diseases, so no exclusions were made. We did not exclude patients with active periodontal disease from the therapy, although we instructed all patients on how to improve their oral hygiene.

The decision to use block grafts, rather than cancellous bone or blocks from the tibia or the hip, was based on the available literature, showing that ramus blocks are superior to the endochonral bone obtained from ilium or tibia.[11,12] Moreover, ramus cortical bone grafts offer some advantages prior to implant placement. These grafts maintain their bone density and have only a small tendency to resorb. Finally, these grafts have limited side effects compared to other possible intra-oral donor sites, like grafts from the symphysis area of the mandible which are associated with various sequelae, such as neurosensory deficit and severe pain.[13]

The STO® implant provides a unique design, combining an extremely tapered body and sharp, wide threads and a polished neck. In addition, the internal conus and octagon connection have been proven reliable.[14] Based on the success rate which is consistent with other types of dental implants,[14-17] the results of this study show that STO® implants are safe and effective for dental implant treatment in cases of poor bone quality and especially in the distal maxilla.

Bibliography

1. Lioubavina-Hack N, Lang NP, Karring T. Significance of primary stability for osseointegration of dental implants. Clinical Oral Implants Research 2006;17(3):244-50.
2. Abbou M. Primary stability and osseointegration: preliminary clinical results with a tapered diminishing-thread implant. Practical Procedings and Aestheict Dentistry 2003;15(2):161-8; quiz 170.
3. Esposito M, Coulthard P, Thomsen P, Worthington HV. Interventions for replacing missing teeth: different types of dental implants. Cochrane Database System Review 2005(1):CD003815.
4. Lekholm U, Zarb GA. Patient selection and preparation. In: Branemark PI, Zarb G, Albrektsson T, editors. Tissue integrated prosthesis: osseointegration in clinical dentistry. Chicago: Quintessence, 1985:199-210.
5. Intercooled Stata. Version 9.0. College Station, TX: Stata Corporation. 2005.
6. Akkocaoglu M, Uysal S, Tekdemir I, Akca K, Cehreli MC. Implant design and intraosseous stability of immediately placed implants: a human cadaver study. Clinical Implant Dentistry and Related Research 2005;16(2):202-9.
7. O'Sullivan D, Sennerby L, Meredith N. Measurements comparing the initial stability of five designs of dental implants: a human cadaver study. Clinical Implant Dentistry and Related Research 2000;2(2):85-92.
8. Friberg B, Jisander S, Widmark G, Lundgren A, Ivanoff CJ, Sennerby L, et al. One-year prospective three-center study comparing the outcome of a 'soft bone implant' (prototype Mk IV) and the standard Branemark implant. Clinical Implant Dentistry and Related Research 2003;5(2):71-7.
9. Ostman PO, Hellman M, Wendelhag I, Sennerby L. Resonance frequency analysis measurements of implants at placement surgery. International Journal of Prosthodontics 2006;19(1):77-83; discussion 84.
10. Barewal RM, Oates TW, Meredith N, Cochran DL. Resonance frequency measurement of implant stability in vivo on implants with a sandblasted and acid-etched surface. The International Journal of Oral and Maxillofacial Implants 2003;18(5):641-51.
11. Carinci F, Farina A, Zanetti U, Vinci R, Negrini S, Calura G, et al. Alveolar ridge augmentation: A comparative longitudinal study between calvaria and iliac crest bone grafrs. Journal of Oral Implantology 2005;31(1):39-45.
12. Lu M, Rabie AB. Quantitative assessment of early healing of intramembranous and endochondral autogenous bone grafts using micro-computed tomography and Q-win image analyzer. The International

Journal of Oral Maxillofacial Implants 2004;33(4):369-76.
13. Misch C. Use of the mandiublar ramus as a donor site for onlay bone grafting. Journal of Oral Implantology 2000;26(1):42-49.
14. Astrand P, Engquist B, Anzen B, Bergendal T, Hallman M, Karlsson U, et al. A three-year follow-up report of a comparative study of ITI Dental Implants and Branemark System implants in the treatment of the partially edentulous maxilla. Clinical Implant Dentistry and Related Research 2004;6(3):130-41.
15. Behneke A, Behneke N, d'Hoedt B. A 5-year longitudinal study of the clinical effectiveness of ITI solid-screw implants in the treatment of mandibular edentulism. The International Journal of Oral Maxillofacial Implants 2002;17(6):799-810.
16. Fugazzotto PA, Vlassis J, Butler B. ITI implant use in private practice: clinical results with 5,526 implants followed up to 72+ months in function. The International Journal of Oral Maxillofacial Implants 2004;19(3): 408-12.
17. Nentwig GH. Ankylos implant system: concept and clinical application. Journal of Oral Implantology 2004;30(3):171-7.

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