*Roland Glauser*
*Lars Sennerby*
*Neil Meredith*
*Andreas Rée*
*AnnaKarin Lundgren*
*Jan Gottlow*
*Christoph H. F. Hämmerle*

# Resonance frequency analysis of implants subjected to immediate or early functional occlusal loading

## Successful vs. failing implants

**Authors' affiliations:**
*Roland Glauser, Andreas Rée, Christoph H. F. Hämmerle*, Department for Fixed and Removable Prosthodontics, University of Zurich, Zurich, Switzerland
*Lars Sennerby, AnnaKarin Lundgren, Jan Gottlow*, Department of Biomaterials, University of Gothenburg, Gothenburg, Sweden
*Neil Meredith*, Department of Restorative Dentistry, Leeds Dental Institute, Leeds, UK

**Correspondence to:**
*Dr Roland Glauser*
Department for Fixed and Removable Prosthodontics
University of Zurich
Plattenstrasse 11
CH 8028 Zurich
Switzerland
Tel.: +41 1 6343251
Fax: +41 1 6344305
e-mail: glauser@zzmk.unizh.ch

**Key words:** clinical study, dental implants, immediate loading, implant stability, resonance frequency analysis

**Abstract**

**Objectives:** The objective of this study was to analyze the development of implant stability by repeated resonance frequency analysis (RFA) measurements during 1 year in 23 patients treated according to an immediate/early-loading protocol. The objective was also to evaluate the possible differences between failing and successful implants.

**Material and methods:** Eighty-one Brånemark System implants were placed in 23 patients for immediate/early-occlusal loading in all jaw regions. Thirty of the implants were placed in extraction sockets and 62 were subjected to GBR procedures. Apart from clinical and radiographic examinations, the patients were followed with RFA at placement, prosthesis connection and after 1–3, 6 and 12 months. Statistical analyses were carried out to study the possible differences between implants that failed during the study period and implants that remained successful.

**Results:** Nine implants failed (11.2%) during the 1 year of loading. RFA showed a distinct different pattern between the implants that remained stable and the implants that were lost. The implants that failed during the course of the study showed a significantly lower stability already after 1 month.

**Conclusion:** Within the limitations of this study, it is concluded that failing implants show a continuous decrease of stability until failure. Low RFA levels after 1 and 2 months seem to indicate an increased risk for future failure. This information may be used to avoid implant failure in the future by unloading implants with decreasing degree of stability with time as diagnosed with the RFA technique.

The implant literature shows that good and predictable outcomes can be expected when using Brånemark implants for oral rehabilitation of totally and partially edentulous patients when following a two-stage protocol (Esposito et al. 1998). Based on the long experience and the generally good results, it appears natural to try to simplify the procedure and to shorten the time required for the treatment without jeopardizing the clinical result. Although some reports have been published earlier (Ledermann 1984; Schnitman et al. 1990), more attention has been paid to immediate implant restoration procedures in the literature of the last few years (Henry & Rosenberg 1994; Salama et al. 1995; Balshi & Wolfinger 1997; Schnitman et al. 1997; Tarnow et al. 1997). Clinical follow-up studies have demonstrated the possibility of using early/immediate-loading protocols in the anterior mandible for a fixed complete denture on implants in the anterior or posterior mandible (Balshi & Wolfinger 1997; Brånemark

**Date:**
Accepted 1 September 2003

**To cite this article:**
Glauser R, Sennerby L, Meredith N, Rée A, Lundgren AK, Gottlow J, Hämmerle CHF. Resonance frequency analysis of implants subjected to immediate or early functional occlusal loading. Successful vs. failing implants.
*Clin. Oral Impl. Res.* **15**, 2004; 428–434
doi: 10.1111/j.1600-0501.2004.01036.x

et al. 1999; Randow et al. 1999; Ericsson et al. 2000b; Maló et al. 2003) or overdenture on implants in the anterior or posterior mandible (Chiapasco et al. 1997, 2001, 2003; Gatti et al. 2000; Payne et al. 2001; Roynesdal et al. 2001), for single tooth replacements or small fixed partial dentures in the maxilla and the mandible (Wöhrle 1998; Ericsson et al. 2000a, 2000b; Maló et al. 2000; Chaushu et al. 2001; Calandriello et al. 2003; Rocci et al. 2003a, 2003b) as well as for the totally edentulous maxilla (Tarnow et al. 1997; Horiuchi et al. 2000; Jaffin et al. 2000; Olsson et al. 2003). In these studies, most authors used strict inclusion criteria, where smokers and bruxers were excluded. In a recent publication on immediate occlusal implant loading, no restrictions regarding age, smoking, bruxism, bone quality, bone defects, implant length, crown–implant ratio, as well as extension of the reconstruction were imposed (Glauser et al. 2001b). Hence, after 1 year of loading, 22 of 127 implants were lost. It was evident that implant failure was more frequent in the posterior maxilla and in patients with parafunctional habits. Thus, the results point to the fact that situations for a risk of relative overloading, due to weak bone support and/or high levels of loading, constitute an increased risk for implants failure, at least for immediate/early-loading protocols.

When applying early/immediate loading, the implant–bone system is biomechanically challenged during healing. The type and magnitude of loading will probably influence the ongoing healing process and it is possible that in some cases, this may lead to demineralization of the bone–implant interface, loss of stability and eventually implant failure. The development of the resonance frequency analysis (RFA) technique according to Meredith et al. (1996) has given the researcher and clinician the possibility of measure implant stability, as a function of bone–implant interface stiffness, at various time points during the treatment. Because one-stage implants are piercing the mucosa following their insertion, RFA measurements are well suitable for analyzing the influence of immediate/early loading on the bone–implant interface stiffness and implant stability.

The objective of this study was to analyze the development of implant stability by repeated RFA measurements during 1 year in 23 patients treated according to an immediate/early-loading protocol. The objective was also to evaluate the possible differences between failing and successful implants.

## Material and methods

### Subjects

Twenty-three patients participated in the study and constituted a subgroup of a larger group of patients treated according to an immediate/early-loading protocol as previously described (Glauser et al. 2001b).

The patient inclusion criteria were:

1. Height and volume of the alveolar bone for placement of implants with a minimum length of 7 mm in a restoration-driven direction;
2. No granulation tissue or signs of acute infections in case of implantation in an immediate extraction socket;
3. No signs of pathology of the maxillary sinus (when placing implants in the posterior part of the maxilla);
4. Sufficient primary implant stability as judged clinically.

All prosthetic indications such as single, partial and total edentulism were included. Implant placement in immediate extraction sockets ($n = 30$) were allowed. The use of regenerative procedures in conjunction with implant placement was accepted ($n = 62$) within the study design. Furthermore, smokers as well as patients who showed signs of increased occlusal wear and parafunctional activities such as clenching and/or crunching were also included.

### Clinical procedures

#### Preoperative planning

The preoperative planning was based on clinical and radiographical examinations. The radiographic examination included CT scans, or orthopantomograms and periapical radiographs.

#### Implants

A total of 81 implants (Brånemark System, Nobel Biocare AB, Gothenburg, Sweden) were placed. The majority of the implants ($n = 71$) were tapered screw-shaped titanium implants of the MKIV design with two different diameters (4.0 and 5.0 mm), and lengths ranging from 7 to 18 mm. Moreover, one standard and nine implants of the MKII design with diameter 3.75 and 4.0 mm and 10–18 mm in length were used. All implants had a machined surface.

#### Surgery

A modified drilling technique as previously described (Glauser et al. 2001b) was applied, aiming at a low insertion torque during the first two-third of the insertion path and an increased torque during the last one-third. In brief, this was achieved by using the following sequence of drills: 1.8 mm guide drill; 2 mm twist drill; and 3.0 mm twist drill for all sites. In cases where a wide-platform implant was selected, the site was further prepared with 3.8 and 4.3 mm twist drills. Independent of the implant diameter and length, the osteotomy site was further instrumented using a screw-tap up to the final one-third of the site in cases with dense bone quality (bone quality 1 and 2 according to the index of Lekholm & Zarb (1985)).

Counter-sinking was performed to submerge the implant head in good bone qualities (quality 1 and 2), but used to a limited extent in poor bone qualities (quality 3 and 4).

A clinical evaluation of bone quality and quantity was carried out for each site using the index as described by Lekholm & Zarb (1985). Implants were placed using low rotational speed (30 rpm). The initial individual stability of the implants formed the basis for a decision of whether or not to load them immediately. Implants that could be further rotated when seated or when placing the abutment both using a 10 N cm torque level were not included in the study.

Sites ($n = 62$) with exposed implant threads were treated by guided bone regeneration applying deproteinized bovine bone mineral (Bio-Oss®, Geistlich Söhne AG, Switzerland) and a bioresorbable collagen membrane (Bio-Gide®, Geistlich Söhne AG, Switzerland).

The muco-periosteal flaps were closed with a non-resorbable suture (W.L. Gore & Associates Inc, Flagstaff, AZ, USA). Systemic analgesics/antiflogistics (Ponstan® Pfizer AG, Switzerland, Division Parke-Davis; 4 × 500 mg/day) were prescribed for 4 days and antibiotics (Azillin®, Spirig AG, Switzerland; 3 × 375 mg/day) for 5 days.

Mouth rinsing with a 0.2% chlorhexidine solution was prescribed three times a day during 2 weeks. The sutures were removed at 7–10 days postoperatively.

### Prosthetic protocol

The abutment was selected by the type of prosthetic construction (single tooth: CeraOne®, multiunit bridge: Estheti-Cone® or MirusCone®, bar constructions: Standard abutments (Nobel Biocare AB, Gothenburg, Sweden)). Fixed, provisional prosthetic reconstructions consisted of a metal- or fiber-reinforced framework and an acrylic veneering. The removable reconstructions were anchored with oval bars (Ovoid gold bar system, Nobel Biocare AB, Gothenburg, Sweden) supported by four implants in the mandible and six implants in the maxilla. Cantilevers were avoided in all reconstructions. All prosthetic reconstructions were in full contact in centric occlusion. Excursive contacts on the implant–bone reconstructions were avoided whenever possible. In the majority of cases (71%), the provisional reconstruction was delivered the same day. For all other cases (29%), the patients received the prosthesis at the latest 11 days after fixture insertion. A delay in placement of the reconstruction was due to technical or logistic reasons. For all cases, the provisional reconstruction was used during the first year.

### Measurement parameters

#### Implant survival

Clinical examination of the implants was performed at prosthesis delivery, after 1 and 2 weeks and after 1, 2, 3, 6 and 12 months. Any mobile implant was regarded as a failure and was removed.

#### Resonance frequency analysis

RFA according to Meredith et al. (1996) was performed at implant insertion ($n=81$), prosthesis connection ($n=71$), at 1 ($n=63$), 2 ($n=59$), 3 ($n=60$), 6 ($n=49$) and 12 months ($n=34$) after the delivery of the prosthesis. At each measurement session, the provisional crown, fixed partial/complete denture or bar was removed in order to give access to each single implant. A transducer was connected to the implant or abutment. The transducer beam was excited over a range of frequencies and the resonance frequency (RF) measured by the use of a frequency-response analyzer connected to a laptop computer and run with dedicated software. The RF was seen as a peak in an amplitude–frequency plot of the response of the transducer beam and expressed in Hertz. Several different transducers were used. Since each transducer had a unique fundamental RF, the measurements were calibrated using a calibration block. Abutment length was also calibrated by using the different abutments and lengths on the block.

The values were later transformed to Implant Stability Quotient (ISQ) units, which is presently used to describe implant stability with the RFA technique. A value between 1 and 100 is obtained, where 1 is the lowest and 100 the highest degree of stability.

### Statistical analysis

Descriptive statistics including mean values and standard deviations were used to describe changes of implant stability over time both for successful and failing implants. The Mann–Whitney $U$-test was used for comparison and a significant difference was considered if $P<0.05$ (two-tailed). The statistical tests were based on both the patient and the implant as the unit. If a patient had values from several loaded implants, a mean was calculated and used for patient-based statistics.

## Results

### Implant survival

A total of 81 implants (50 maxillary and 31 mandibular) and 37 prostheses were immediately loaded. At 1 year, nine implants were lost in six patients giving a failure rate of 11.1% after 1 year.

Failures occurred during the study period from 2 to 47 weeks after prosthesis connection.

### Resonance frequency analysis

The RFA measurements showed an RF of 6.48 kHz (ISQ 68) as a mean value, indicating that high primary stability had been achieved for the majority of the implants. The mean stability for all implants decreased to 6.10 kHz (ISQ 60) during the first 2 months, thereafter stabilized and increased up to 12 months when it reached the level measured at prosthesis connection (Fig. 1). The stability was statistically significantly lower after 1–3 and 6 months compared with the first measurement.

Implants that failed during the course of the study showed a distinct different pattern from the implants that remained successful (Fig. 2). The difference was clearly discernible and statistically significant from 1 month after prosthesis connection both when using the patient and the implant as the unit. Failing implants showed decreased stability until loss of the implant (Fig. 3).

It is interesting to note that after 1 month, when the RFA of failing implants was significantly lower than the successful ones, only two of nine failures had occurred (22.2%). The findings indicate that RFA could identify failing implants after 1 month, before failure of the majority of the implants was clinically manifested. Table 1 shows the calculated risk for future

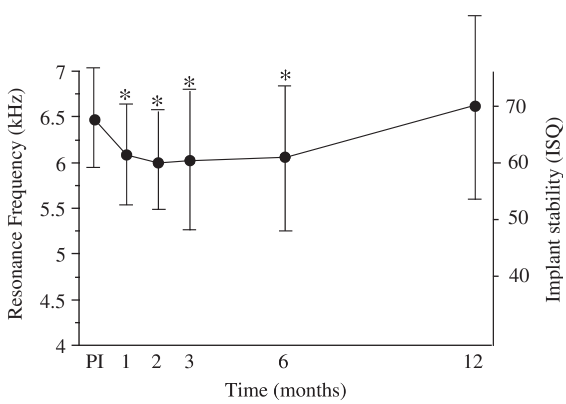


*Fig. 1.* Mean implant stability (Hz ± SD on left $y$-axis and Implant Stability Quotient (ISQ) ± SD on right $y$-axis) for all implants at placement and after 1–3, 6 and 12 months. The stability was statistically significant lower after 1–3 and 6 months compared with the first measurement ($P<0.05$).

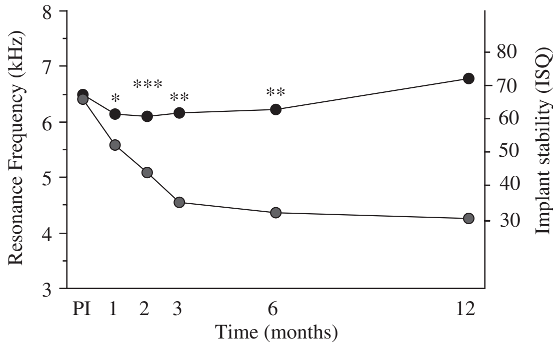


*Fig. 2*. Mean implant stability (Hz ± SD on left *y*-axis and Implant Stability Quotient (ISQ) ± SD on right *y*-axis) against time for implants that failed and for implants that remained stable during the study. Statistically significant differences between the failed and successful group was seen after 1–3 and 6 months ($P<0.05$).

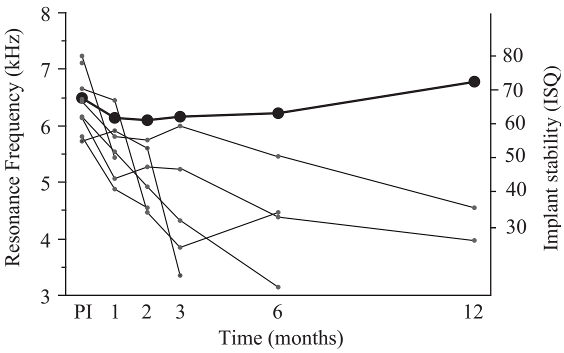


*Fig. 3*. Implant stability with time for implants that eventually failed. The bold line indicates the mean stability for all successful implants.

***Table 1*. Failure rates after one year for implants found in different Implant Stability Quotient (ISQ) intervals based on RFA measurements after 1 and 2 months**

| ISQ | Failure rate after 1 year (%) |
|---|---|
| *At 1 month* | |
| >69 | 0 |
| 59–68 | 5.6 |
| 49–58 | 18.2 |
| 39–48 | 33.3 |
| <39 | 100 |
| *At 2 months* | |
| >69 | 0 |
| 59–68 | 0 |
| 49–58 | 13.3 |
| 39–48 | 13.3 |
| <39 | 100 |

failure based on RFA measurements at the 1- and 2-month check-up appointments.

## Discussion

The analysis of the RFA data after completion of the study showed that the technique was sensitive to identify failing implants before complete loss. In this study, RFA was used blindly as one additional parameter in the follow-up of the patients with immediately loaded implants, meaning that the clinician was not aware of the results of the measurements until after the study period. Therefore, the information could not be used chair side to take measures to avoid failure, for instance by unloading implants showing falling RFA values. Thus, all implants received the same treatment irrespective of a high or a low RFA value and no implants were unloaded despite a decreasing RFA value.

With the experimental version of the RFA equipment as used in the present study, the different transducers had different fundamental RFs and had to be calibrated before comparison. Since the time the study was initialized, the RFA technique has been made commercially available (OSSTELL, Integration Diagnostics, Sävedalen, Sweden). With the developed technique, all transducers are calibrated from the manufacturer and the results are expressed in ISQs instead of Hertz. The ISQ value is based on the underlying and calibrated RF of the transducer and is given as a number from 1 to 100 where 1 is the lowest and 100 the highest degree of stability. The new technique allows for chair-side measurements where the clinician immediately can compare the measurement with former ones or to a 'standard' value for that situation. If this equipment had been available in the present study, it is possible that the failing implants could have been rescued by unloading them when the stability value dropped with time. Friberg et al. (1999c) used RFA for monitoring of the stability of one-staged implants in the mandible during 15 weeks. In a patient with a history of parafunction, they found loss of RFA values for three of five implants after 6 weeks due to overload from the relined denture. By asking the patient to refrain from using the denture during the coming 9 weeks before fixed complete denture delivery, the RFA values of these implants increased again and the implants could be used as abutments for the final reconstruction. It was suggested that the implants showing a decrease in the RFA value with time should be unloaded until a sufficient degree of stability has been reached again. However, more studies are needed to establish normal levels of stability. Sennerby & Meredith (2002) suggested that implants with a primary stability above ISQ 60–65 may be suitable for immediate loading, while implants below 40 may be more prone to failures according to preliminary experiences with two-stage implants (Sennerby & Meredith 2002). In the present study, there was no difference in primary stability between implants that finally failed and the ones that remained stable during the study. However, after 2 months the failing implants showed a mean ISQ of 43 and the successful implants maintained a stability around ISQ 60. Hence, it is mandatory to remeasure implant stability at later time points in order to be able to detect failing implants.

Primary implant stability is determined by the bone density, the implant design and the surgical technique. Previous follow-up studies have demonstrated higher failure rates in soft bone qualities (Jaffin & Berman 1991; Friberg et al. 1991), which suggest that the degree of primary stability is important for the clinical outcome. However, more recent studies have shown similar good results in soft as in dense bone (Friberg et al. 1999a; Bahat 2000). It may be speculated that this is attributed to changes of the surgical technique in order to reach firm primary stability, including reduced drill diameters, the use of self-tapping implants, wider implants and tapered implants. The early protocol for the placement of Brånemark implants included the use of a screw-tap to thread each implant site and subsequent placement of an implant with no self-tapping features, which may have resulted in a poor primary stability, especially in soft bone. In the present study, reduced drill diameters were used to ensure high primary stability. Moreover, the majority of the implants placed were of a tapered design. In a human cadaver study, O'Sullivan et al. (2000) demonstrated higher RFA values for tapered implants than for non-tapered implants. Glauser et al. (2001a) found significantly higher RFA values for tapered implants (Brånemark System, Mk IV) than for non-tapered implants (Brånemark System, Mk II and Mk III) in a comparative clinical study using RFA. Moreover, a recent multicenter study compared a tapered implant design (MKIV, Brånemark System) with a non-tapered implant (standard fixture, Brånemark System) in the posterior maxilla (Friberg et al. 2003). Higher RFA values were achieved with the tapered implant but there was no statistically significant difference between the survival rates of the two implant designs, although more control implants were lost during 1 year in function. The use of tapered implants in combination with a modified drilling technique in the present study may explain the lack of difference between implants placed in different bone qualities as previously demonstrated by Friberg et al. (1999b). They found a correlation between the bone quality and RFA value when placing non-tapered implants in edentulous maxillae. The data obtained in the present study are in line with O'Sullivan et al. (2000), who showed similar RFA values for tapered implants irrespective of bone quality in a human cadaver material.

The mechanism behind the fall of ISQ during the first 3 months in the present study is probably related to changes of the bone–implant interface as well as the properties of the surrounding bone (i.e. interfacial stiffness). Firstly, the tapered implant creates a lateral compression of the bone tissue during insertion. It is likely that relaxation of inbuilt stresses between the implant and bone occurs after implant placement, which can be seen as a decrease in ISQ. Secondly, it can be speculated that loading may induce microfractures in the surrounding bone. Thirdly, it is likely that the healing response to implant surgery itself may result in a decreased stiffness as a result of bone resorption, since extensive remodeling occurs in the cortical bone as a healing reaction to surgical wounding (Sennerby et al. 1993). Moreover, the time for the initial decrease (3 months) and the subsequent increase of ISQ (3–12 months) in the present study matches the time frames of the bone formation and maturation around the dental implants as described by Roberts (1993). According to this investigator, one bone remodeling cycle (activation–resorption–formation) takes about 4 months (one sigma) in humans. Initial bone resorption and formation occurs during the first sigma and maturation requires another two sigmas.

The present study group is a subgroup of patients from a previously published study (Glauser et al. 2001b). The original group comprised 41 patients and 127 implants placed in all jaw regions. A high number of failures were experienced since 22 (17.3%) were lost during 1 year of loading. The statistical analysis showed significantly more failures in the posterior maxilla, in soft bone qualities and in patients with bruxism. It can also be speculated that the repeated removal of the prostheses *per se* had a negative influence of the outcome. The high failure rate in this and the previous study (Glauser et al. 2001b) is in contrast to the outcome of a recent study from our group (Glauser et al. 2003). By following the same protocol, 102 implants with the surface modified by anodic oxidation were placed and loaded in 38 patients. The failure rate was 3% after 1 year of loading due to a postoperative infection. No implants were lost due to overloading. RFA showed a similar pattern as for the successful implants of the present study. These results indicate a positive effect of surface modification on implant survival in immediate/early loading, probably due to an improved performance in the soft bone.

Within the limitations of this study, it is concluded that failing implants show a continuous decrease of stability until failure. Low RFA levels after 1 and 2 months seem to indicate an increased risk for future failures. This information may be used to avoid implant failure in the future by unloading implants with decreasing degree of stability with time as diagnosed with the RFA technique

## Résumé

L'objectif de cette étude a été d'analyser le développement de la stabilité implantaire par des mesures RFA (analyse par fréquence de résonnance) répétées durant une année chez 23 patients traités suivant le protocole de charge immédiat/précoce. L'objectif était aussi d'évaluer les différences possibles entre implants à succès et échecs. Quatre-vingt-un implants *ad modum* Brånemak ont été placés chez 23 patients pour mise en charge immédiate/précoce dans toutes les parties de la bouche. Trente des implants ont été placés dans des alvéoles d'avulsion et soixante-deux ont été soumis à des processus de regénération osseuse guidée ROG. A part les examens cliniques et radiographiques, les patients ont été suivis avec le RFA lors du placement, de la connexion de la prothèse et après un, deux , trois, six et douze mois. Les analyses statistiques ont été faites pour étudier les différences possibles entre les implants à succès et à échec. Neuf implants ont échoué (11,2%) durant l'année de mise en charge. RFA montrait un modèle différent entre les implants qui restaient stables et les implants qui étaient perdus. Les implants qui échouaient durant la période de l'étude montraient une stabilité significativement inférieure déjà après un mois. Dans les limites de l'étude présente, il est conclu que les implants qui échouent montrent une diminution continue de la stabilité jusqu'à l'échec complet. Des niveaux faibles RFA après un et deux mois semblent indiquer une augmentation du risque de l'échec futur. Cette information peut être utilisée pour annuler l'échec implantaire dans le futur en déchargeant les implants avec un degré décroissant de stabilité dans le temps lorsqu'il a été diagnostiqué par la technique RFA.

## Zusammenfassung

**Ziele:** Das Ziel dieser Studie war es, bei 23 Patienten, die nach einem Protokoll der Sofort- oder Frühbelastung behandelt worden waren, die Entwicklung der Implantatstabilität mit Hilfe von wiederhohlten RFA-Messung über ein ganzes Jahr zu verfolgen. Zusätzlich versuchte man eventuelle Unterschiede in dieser Entwicklung zwischen erfolgreichen Implantaten und solchen mit einem Misserfolg herauszufinden.

**Material und Methode:** Bei 23 Patienten wurden in allen vier Quadranten Zahnlücken mit 81 Implantaten des Brånemark-Systems versorgt, die anschliessend okklusal früh oder sofortbelastet wurden. 30 der Implantate setzte man direkt in Extraktionsalveolen und bei 62 musste zusätzlich das Prinzip der GBR angewandt werden. In Ergänzung zu den klinischen und röntgenologischen Untersuchungen führte man bei jedem Patienten nach dem Implantieren, nach der prothetischen Rekonstruktion, sowie 1, 2, 3, 6 und 12 Monate später RFA-Messungen durch. Die statistischen Analysen hatten zum Ziel, mögliche Unterschiede zwischen Implantaten, die während der Beobachtungszeit zu einem Misserfolg führten und erfolgreichen Implantaten zu finden.

**Resultate:** 9 Implantate (11.2%) führten im ersten Jahr der okklusalen Belastung zu einem Misserfolg. Die RFA-Veränderungen zeigten bei Implantaten, die erfolgreich waren einen deutlich anderen Verlauf als bei Implantaten, die später verloren gingen. Solche Implantate, die bereits während der Studie verloren gingen, zeigten bereits nach einem Monat eine signifikant tiefere Stabilität.

**Zusammenfassung:** Innerhalb der begrenzten Aussagekraft dieser Studie kann man schliessen, dass Implantate, die zu einem Misserfolg führen, bis zu diesem Zeitpunkt kontinuierlich an Stabilität verlieren. Tiefe RFA-Werte nach 1 und 2 Monaten scheinen Zeichen für eine erhöhtes Risiko für einen Misserfolgs zu sein. Diese Informationen können so verwendet werden, dass man Implantate gemäss dem abnehmenden Stabilitätsgrad, diagnostiziert durch die RFA-Technik, später okklusal belastet. Damit lässt sich ein zukünftiger Implantatmisserfolg vermeiden.

## Resumen

**Objetivos:** El objetivo de este estudio fue analizar el desarrollo de la estabilidad implantaria por medio de mediciones RFA repetidas durante un año en 23 pacientes tratados de acuerdo con un protocolo de carga inmediata/temprana. El objetivo fue también evaluar posibles diferencias entre implantes fracasando o exitosos.

**Material y Métodos:** Se colocaron ochenta y un (81) implantes del sistema Brånemark en 23 pacientes para carga oclusal inmediata en todas las regiones mandibulares. Se colocaron treinta (30) implantes en alvéolos de extracción y 62 fueron sometidos a procedimientos de GBR. Aparte de los exámenes clínicos y radiológicos, los pacientes fueron seguidos con RFA al colocarse, al conectar la prótesis y tras 1, 2, 3, 6 y 12 meses. El análisis estadístico se llevó a cabo para estudiar las posibles diferencias entre los implantes que fracasaron durante el periodo del estudio y los implantes que permanecieron con éxito.

**Resultados:** Nueve (9) implantes fracasaron (11.2%) durante el año de carga. El RFA mostró un claro patrón diferente entre los implantes que permanecieron estables y los implantes que se perdieron. Los implantes que fracasaron en el curso del estudio mostraron una estabilidad significativamente menor tras un mes.

**Conclusión:** Dentro de los límites de este estudio, se concluye que los implantes que fracasan muestran un descenso continuo de la estabilidad hasta el fracaso. Unos niveles bajos de RFA tras 1 o 2 meses parecen indicar un riesgo mayor para un futuro fracaso. Esta información puede ser usada para evitar el fracaso del implante en el futuro descargando los implantes con un decreciente grado de estabilidad en el tiempo diagnosticada por la técnica de RFA.

要旨

目的：本研究は、即時／早期荷重のプロトコールに基づいて治療を受けた２３名の患者について１年間ＲＦＡの測定を行い、インプラントの安定度の変化を分析した。また失敗しつつあるインプラントと成功しているインプラントの差異についても評価した。

材料と方法:患者２３名の顎骨のあらゆる領域に、８１本の Branemark システム・インプラントを埋入し、即時／早期荷重した。インプラント３０本は抜歯窩に埋入し、６２本はＧＢＲの処置を行った。患者は、臨床検査とレントゲン検査に加えて埋入時、補綴物連結時、１、２、６、１２ヵ月後にＲＦＡを測定して、経過観察した。統計分析を行い、研究期間中に失敗したインプラントと成功したインプラントの間の差異について検討した。

結果：９本のインプラント（１１．２％）は、荷重後１年の間に失敗した。ＲＦＡは、安定したインプラントと失われたインプラントの間で明らかに異なるパターンを示した。経過観察中に失われたインプラントは、すでに１ヶ月後に安定性が有意に損なわれていた。

結論：本研究の制約内において、失敗するインプラントは喪失するまで安定性が連続的に減少してゆくと結論された。１、２ヶ月後のＲＦＡが低いレベルの場合、将来の失敗のリスクが増加するように思われる。本情報を用いて、ＲＦＡの測定によって経時的に安定性が減少していると診断されたインプラントを免荷することによって、将来のインプラントの失敗を防ぐことができると思われる。

## References

Bahat, O. (2000) Branemark system implants in the posterior maxilla: clinical study of 660 implants followed for 5 to 12 years. *International Journal of Oral & Maxillofacial Implants* **15**: 646–53.

Balshi, T.J. & Wolfinger, G.J. (1997) Immediate loading of Brånemark implants in edentulous mandibles. A preliminary report. *Implant Dentistry* **6**: 83–88.

Brånemark, P.I., Engstrand, P., Öhrnell, L.O., Gröndahl, K., Nilsson, P., Hagberg, K., Darle, C. & Lekholm, U. (1999) Brånemark Novum. A new treatment concept for rehabilitation of the edentulous mandible preliminary results from a prospective clinical follow-up study. *Clinical Implant Dentistry and Related Research* **1**: 2–16.

Calandriello, R., Tomatis, M., Vallone, R., Rangert, B. & Gottlow, J. (2003) Immediate occlusal loading of single lower molars using Brånemark system wide-platform TiUnite implants: an interim report of a prospective open-ended clinical multicenter study. *Clinical Implant Dentistry and Related Research* **5** (Suppl. 1): 74–80.

Chaushu, G., Chaushu, S., Tzohar, A. & Dayan, D. (2001) Immediate loading of single-tooth implants: Immediate *versus* non-immediate implantation. A clinical report. *International Journal of Oral & Maxillofacial Implants* **16**: 267–272.

Chiapasco, M., Abati, S., Romeo, E. & Vogel, G. (2001) Implant-retained mandibular overdentures with Brånemark System MkII implants: A prospective comparative study between delayed and immediate loading. *International Journal of Oral & Maxillofacial Implants* **16**: 537–546.

Chiapasco, M. & Gatti, C. (2003) Implant-retained mandibular overdentures with immediate loading: a 3- to 8-year prospective study on 328 implants. *Clinical Implant Dentistry and Related Research* **5**: 29–38.

Chiapasco, M., Gatti, C., Rossi, E., Haefliger, W. & Markwalder, T.H. (1997) Implant-retained mandibular overdentures with immediate loading. A retrospective multicenter study on 226 consecutive cases. *Clinical Oral Implants Research* **8**: 48–57.

Ericsson, I., Nilsson, H., Lindh, T., Nilner, K. & Randow, K. (2000a) Immediate functional loading of Brånemark single tooth implants. *Clinical Oral Implants Research* **11**: 26–33.

Ericsson, I., Randow, K., Nilner, K. & Peterson, A. (2000b) Early functional loading of Brånemark dental implants. 5-year clinical follow-up study. *Clinical Implant Dentistry and Related Research* **2**: 70–77.

Esposito, M., Hirsch, J.M., Lekholm, U. & Thomsen, P. (1998) Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. *European Journal of Oral Science* **106**: 527–51.

Friberg, B., Jemt, T. & Lekholm, U. (1991) Early failures in 4641 consecutively placed Brånemark dental implants: a study from stage 1 surgery to the connection of completed prostheses. *International Journal of Oral & Maxillofacial Implants* **6**: 142–146.

Friberg, B., Jisander, S., Widmark, G., Lundgren, A.K., Ivanoff, C.J., Sennerby, L. & Thorén, C. (2003) One-year prospective three-center study comparing the outcome of a ''soft bone implant'' (Prototype Mk IV) and the standard Brånemark Implant. *Clinical Implant Dentistry and Related Research* **5**: 71–77.

Friberg, B., Sennerby, L., Gröndahl, K., Bergström, C., Bäck, T. & Lekholm, U. (1999a) On cutting torque measurements during implant placement. A 3-year clinical prospective study. *Clinical Implant Dentistry and Related Research* **1**: 75–83.

Friberg, B., Sennerby, L., Linden, B., Gröndahl, K. & Lekholm, U. (1999b) Stability measurements of one-stage Brånemark implants during healing in mandibles. A clinical resonance frequency study. *International Journal of Oral and Maxillofacial Surgery* **28**: 266–272.

Friberg, B., Sennerby, L., Meredith, N. & Lekholm, U. (1999c) A comparison between cutting torque and resonance frequency measurements of maxillary implants – a 20-month clinical study. *International Journal of Oral and Maxillofacial Surgery* **28**: 297–303.

Gatti, C., Haefliger, W. & Chiapasco, M. (2000) Implant-retained mandibular overdentures with immediate loading. A prospective study of ITI implants. *International Journal of Oral & Maxillofacial Implants* **15**: 383–388.

Glauser, R., Lundgren, A.K., Gottlow, J., Sennerby, L., Portmann, M., Ruhstaller, P. & Hämmerle, C.H.F. (2003) Immediate occlusal loading of Brånemark TiUnite implants placed predominantly in soft bone: 1-year results of a prospective study. *Clinical Implant Dentistry and Related Research* **5** (Suppl. 1): 47–56.

Glauser, R., Portmann, M., Ruhstaller, P., Gottlow, J. & Schärer, P. (2001a) Initial implant stability using different implant designs and surgical techniques. A comparative clinical study using insertion torque and resonance frequency analysis. *Applied Osseointegration Research* **2**: 6–8.

Glauser, R., Rée, A., Lundgren, A.K., Gottlow, J., Hämmerle, C.H.F. & Schärer, P. (2001b) Immediate occlusal loading of Brånemark implants applied in various jawbone regions: prospective, 1-year clinical study. *Clinical Implant Dentistry and Related Research* **3**: 204–213.

Henry, P. & Rosenberg, I. (1994) Single-stage surgery for rehabilitation of the edentulous mandible: preliminary results. *Practical Periodontics and Aesthetic Dentistry* **6**: 15–22.

Horiuchi, K., Uchida, H., Yamamoto, K. & Sugimura, M. (2000) Immediate loading of Brånemark system implants following placement in edentulous patients: a clinical report. *International Journal of Oral and Maxillofacial Implants* **15**: 824–830.

Jaffin, R.A. & Berman, C.L. (1991) The excessive loss of Brånemark fixtures in type IV bone: a 5-year analysis. *Journal of Periodontology* **62**: 2–4.

Jaffin, R.A., Kumar, A. & Berman, C.L. (2000) Immediate loading of implants in partially and fully edentulous jaws. A series of 27 case reports. *Journal of Periodontology* **71**: 833–838.

Ledermann, P.D. (1984) Das TPS-Schraubenimplantat nach siebenjähriger Anwendung. *Quintessenze* **30**: 1–11.

Lekholm, U. & Zarb, G.A. (1985) Patient selection and preparation. In: Brånemark, P.I., Zarb, G.A. & Albrektsson, T., eds. *Tissue-integrated prostheses: osseointegration in clinical dentistry*, 199–210. Chicago: Quintessence.

Maló, P., Rangert, B. & Dvärsäter, L. (2000) Immediate function of Brånemark implants in the esthetic zone: a retrospective clinical study with 6 months to 4 years of follow-up. *Clinical Implant Dentistry and Related Research* **2**: 138–146.

Maló, P., Rangert, B. & Nobre, M. (2003) All-on-Four immediate-function concept with Brånemark system implants for completely edentulous mandible: a retrospective clinical study. *Clinical Implant Dentistry and Related Research* **5** (Suppl. 1): 2–9.

Meredith, N., Alleyne, D. & Cawley, P. (1996) Quantitative determination of the stability of the implant-tissue interface using resonance frequency analysis. *Clinical Oral Implants Research* **7**: 261–7.

Olsson, M., Urde, G., Andersen, J.B. & Sennerby, L. (2003) Early loading of maxillary fixed cross-arch dental prostheses supported by 6 or 8 oxidized titanium implants – results after 1 year of loading, case series. *Clinical Implant Dentistry and Related Research* **5** (Suppl. 1): 81–87.

O'Sullivan, D., Sennerby, L. & Meredith, N. (2000) Measurements comparing the initial stability of five designs of dental implants: a human cadaver study. *Clinical Implant Dentistry and Related Research* **2**: 85–92.

Payne, A., Tawse-Smith, A., Kumare, R. & Thomson, M. (2001) One-year prospective evaluation of the early loading of unsplinted conical Brånemark fixtures with mandibular overdentures immediately following surgery. *Clinical Implant Dentistry and Related Research* **3**: 9–19.

Randow, K., Ericsson, I., Nilner, K., Petersson, A. & Glantz, P.O. (1999) Immediate functional loading of Brånemark dental implants. An 18-month clinical follow-up study. *Clinical Oral Implants Research* **10**: 8–15.

Roberts, E.W. (1993) Bone physiology and metabolism. In: Misch, C.E., ed. *Contemporary implant dentistry*, 327–354. St. Louis: Mosby.

Rocci, A., Martignoni, M. & Gottlow, J. (2003a) Immediate loading in the maxilla using flapless surgery, implants placed in predetermined positions and prefabricated provisional restorations. A retrospective 3-year clinical study. *Clinical Implant Dentistry and Related Research* **5** (Suppl. 1): 29–36.

Rocci, A., Martignoni, M. & Gottlow, J. (2003b) Immediate loading of Brånemark system TiUnite and machined surface implants in the posterior mandible: a randomized open-ended clinical trial. *Clinical Implant Dentistry and Related Research* **5** (Suppl. 1): 57–63.

Roynesdal, A.K., Amundrud, B. & Hannaes, H. (2001) A comparative clinical investigation of 2 early loaded ITI dental implants supporting an overdenture in the mandible. *International Journal of Oral & Maxillofacial Implants* **16**: 246–251.

Salama, H., Rose, L.F., Salama, M. & Betts, N.J. (1995) Immediate loading of bilaterally splinted titanium root-form implants in fixed prosthodontics – a technique reexamined: two case reports. *International Journal of Periodontics & Restorative Dentistry* **15**: 344–61.

Schnitman, P.A., Wöhrle, P.S. & Rubenstein, J.E. (1990) Immediate fixed interim prostheses supported by 2-stage threaded implants. Methodology and results. *Journal of Oral Implantology* **16**: 96–105.

Schnitman, P.A., Wöhrle, P.S., Rubenstein, J.E., DaSilva, J.D. & Wang, N.H. (1997) Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. *International Journal of Oral & Maxillofacial Implants* **12**: 495–503.

Sennerby, L. & Meredith, N. (2002) Analisi della freuqenza di resonanza (RFA). Conoscenze attuali e implicazioni cliniche. In: Chiapasco, M. & Gatti, C., eds. *Osteointegrazione e carico immediato. Fondamenti biologici e applicazioni cliniche*, 19–31. Milan: Masson.

Sennerby, L., Thomsen, P. & Ericson, L.E. (1993) Early bone tissue response to titanium implants inserted in rabbit cortical bone. I. Light microscopic observations. *Journal of Material Science: Materials in Medicine* **4**: 240–250.

Tarnow, D.P., Emtiaz, S. & Classi, A. (1997) Immediate loading of threaded implants at stage 1 surgery in edentulous arches. Ten consecutive case reports with 1- to 5-year data. *International Journal of Oral & Maxillofacial Implants* **12**: 319–324.

Wöhrle, P. (1998) Single tooth replacement in the aesthetic zone with immediate provisionalization: fourteen consecutive case reports. *Practical Periodontics and Aesthetic Dentistry* **9**: 1107–1114.