A prospective case-control clinical trial comparing 1- and 2-stage Nobel Biocare TiUnite implants: Resonance frequency analysis assessed by Osstell Mentor during integration

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**Objective:** To compare implant stability between 1- and 2-stage Nobel Biocare TiUnite implants at various points of time after placement. **Method and Materials:** Thirty patients were enrolled according to specific selection criteria to 1- or 2-stage treatment. Nineteen patients received 35 1-stage early loaded implants, and 10 patients received 26 2-stage early loaded implants. A total of 32 Brånemark System MKIII Groovy and 29 NobelSpeedy Groovy implants were placed in the premolar and molar areas. Implant stability was assessed, in both groups, by means of the Osstell Mentor device at the time of implant placement and at 8 and 12 weeks. All patients were monitored from implant placement until 6 months of function. **Results:** One 1-stage complicated implant showed discontinuous measurements, and this patient was excluded from the analysis. In the maxilla (31 implants), there was no significant difference for implant stability quotients between the groups at any point (\(P > .05\)). In the mandible (29 implants), there was no significant difference for ISQ between the groups at baseline or 8 weeks (\(P > .05\)); however, a significant difference was found after 12 weeks (\(P = .0261\)). No implant failed between surgery and the end of the study, and there was an overall survival rate of 100%. **Conclusion:** High ISQ values were found in both groups at each time point. One-stage technique is a viable alternative to 2-stage technique. The utilized implants seem to be suitable for early loading in both arches. NobelSpeedy Groovy showed a higher primary anchorage, especially in the maxilla. *(Quintessence Int 2011;42:635–644)*

**Key words:** dental implants, implant stability, implant surface modification, implant survival, osseointegration, resonance frequency analysis

The integration and healing processes of dental implants were first described in studies on osseointegration.\(^1\)-\(^3\) Osseointegration was originally defined by Brånemark as the direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant.\(^4\) Primary implant stability is one of the prerequisites for achievement and maintenance of osseointegration,\(^5\) and it depends on the mechanical engagement of an implant with the fresh bone socket. Several factors affect the process through which osseointegration is achieved: the biocompatibility of the metal used as well as the design and surface conditions of the implant, the condition of the host bed, the surgical technique, and the loading conditions.\(^6\) Clinical protocols originally suggested a 3- to 6-month healing period before implant loading.\(^7\) Different placement and loading protocols evolved\(^1\)-\(^3\) in response to increased demand for shorter treatment times and less surgery. As such, the clinician can choose between a 1- and 2-stage implant placement protocol. According to the Cochrane systematic review by Esposito et al.,\(^7\) the 1-stage approach seems to be preferable in partially edentulous patients since it avoids a surgical intervention and shortens treat-
ment time. However, trends suggest fewer implant failures with the 2-stage approach, especially in fully edentulous patients.

The aim of this study was to monitor longitudinally the development of implant stability of the Nobel Biocare dental implants (Nobel Biocare) during healing period in 1- and 2-stage surgical approaches and compare them.

**METHOD AND MATERIALS**

This prospective study was designed as a controlled, parallel-group clinical trial, reported according to the Consolidated Standards of Reporting Trials (CONSORT).13

Since the study design was developed as a prospective observation, no statistical method was applied to determine adequate sample size. Instead, the authors attempted to maximize the number of subjects within the limitations of the allowable study budget so as to collect nonbiased, generalizable results. Patients requiring one or more dental implants in the posterior area (premolars and molars) of both the maxilla and mandible, who were 20 years or older, and able to sign an informed consent form were recruited for placement of 1-stage (study group, SG) or 2-stage (control group, CG) implants. Periapical radiographs were used for initial screening. Inclusion criteria were:

- Patients who have smoked fewer than 10 cigarettes a day within the past year
- Adequate oral hygiene (defined as an average Modified Sulcus Bleeding Index of 1 or less and an average Modified Plaque Index of 1 or less)
- Adequate bone volume to accommodate the planned endosseous dental implant
- Healthy and adequately restored existing teeth
- Mutually protected occlusion
- Good physical health
- Minimum torque at implant insertion ≥ 35 Ncm

The investigation was conducted according to the principles embodied in the Helsinki Declaration of 1975 for biomedical research involving human subjects, as revised in 2004. At the preliminary visit, the patients were informed about benefits and risks of the clinical trial, asked if they were willing to participate, and were enrolled after signing a consent form. Patient history was recorded; the necessary clinical and radiographic examinations were performed, and a treatment plan was developed. All patients were treated in a private practice in Rome between September 2008 and October 2009, and they were followed for at least 6 months of function.

One experienced surgeon performed all treatments. When planned, tooth extractions were performed at least 6 weeks before implant placement. Patients were instructed to use chlorhexidine mouthwash 0.2% for 1 minute, twice a day, starting 3 days prior to implant placement and thereafter for 1 week. In both groups, a single 2 g dose of prophylactic antibiotic (amoxicillin and clavulanic acid) was administered just 1 hour before surgery.9,10 The surgical protocol included local anesthesia by means of a block technique using a solution of articaine with epinephrine 1:100,000. The incision was performed with a minimally invasive flap elevation. Thirty-two Brånemark System MKIII Groovy and 29 NobelSpeedy Groovy implants were placed according to the manufacturer’s instructions. The diameter of the final drill was chosen according to the bone quality, and an insertion torque of more than 35 Ncm was achieved. In the 1-stage group, the healing abutments were placed just after implant placement, while in the 2-stage group, cover screws were used; they were both screwed after the application of a chlorhexidine 1% gel. After implant placement, all patients received oral and written specific recommendations, depending on the group. Implant-supported temporary restorations were not used during the first 12 weeks after implant placement. After a healing period of 8 weeks, in the SG, an open tray impression was taken using a polyether material (Impregum, 3M ESPE) with a custom open tray (Diatray Top, Dental Kontor), while in the CG, abutment connection was performed. Titanium or zirconia custom abutments and ceramic restorations were fabricated by computer-aided design/computer-aided manufactur-
ing (CAD/CAM) technology (Nobel Biocare Procera System). The final crowns were cemented in both groups using eugenol-free zinc oxide cement (Temp Bond NE, Kerr) for the titanium abutments and RelyX Unicem (3M ESPE) for the zirconia abutments within 12 weeks from implant placement (early loading).

The primary outcome of this study was to compare 1- and 2-stage implant placement protocols by the resonance frequency analysis (RFA), performed by the Osstell Mentor device (Osstell).

The secondary outcome measures were failures of the implants and of the prostheses, and any complication occurred to the end of the follow-up. The success criteria used in this investigation were a modification of the ones suggested by Van Steenberghe,\textsuperscript{11} as depicted in Fig 1.

Intraoral radiographs using a parallel technique strictly perpendicular to the implant-bone interface were taken to evaluate the peri-implant hard tissue alterations.

Furthermore, the different design of early loaded Nobel Biocare TiUnite implants (Brånemark System MKIII Groovy and NobelSpeedy Groovy, Nobel Biocare) was evaluated. The Osstell Mentor is a noninvasive system, based on assessment of resonance frequency,\textsuperscript{12–18} used to calculate the so-called implant stability quotient within the oral cavity and maxillofacial area. The transducer was screwed manually at implant level (Fig 2), and the measurement device was directed perpendicularly, close to the transducer (SmartPeg), but it ensured no contact between them. A brand-new SmartPeg was used for each intervention.\textsuperscript{14} Measurements were taken twice in each direction: one buccopalatal from the buccal side and one mesiodistal from the mesial side. The result is displayed by the device in ISQ units, which range from 1 to

**Success criteria of the study**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
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<tbody>
<tr>
<td>Does not cause allergic, toxic, or gross infectious reactions locally or systematically</td>
<td>Offers anchorage to a functional prosthesis</td>
</tr>
<tr>
<td>Does not show any sign of fracture or bending</td>
<td>Does not show any sign of radiolucency on an intraoral radiograph using a paralleling technique strictly perpendicular to the implant-bone interface.</td>
</tr>
<tr>
<td>Shows ISQ value ≥ 65 at 8 and 12 weeks</td>
<td>Does not show any mobility when individually tested by tapping or rocking with a hand instrument after implant loading</td>
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</table>

**Fig 1** Modified success criteria originally suggested by Van Steenberghe.\textsuperscript{11}

**Fig 2** The transducers (Smartpeg) manually screwed to the implants.
The mean of these measurements was used. Clinicians who were otherwise not involved in the study performed the data measurements. All implants in both groups were analyzed at implant placement (baseline) and after 8 and 12 weeks. During healing period, RFA was also performed in the 1-stage group at 2, 4, and 6 weeks. The hypothesis to demonstrate was that mean ISQ values in both groups were not different.

To achieve a higher sample size, each eligible private patient between September 2008 and October 2009 was enrolled in this study, but no method has been applied to determine the sample size.

An independent external assistant dispensed either MKIII Groovy or NobelSpeedy Groovy dental implants according to a simple manually generated randomization performed just before the surgery.

**Statistical analysis**

The statistical analysis was performed for numeric parameters such as ISQ values. XL Stat Professional (Addinsoft) and Visual Basic for Application for Windows (Microsoft) were used. A descriptive statistical analysis was performed using mean, standard deviation, and 95% confidence interval (CI). The statistical analysis of ISQ values for both groups was performed at the baseline and at 8 and 12 weeks. Both SG and CG were analyzed as independent parallel groups. The patient was used as the statistical unit, ie, where more than two implants were present on one or both sides of the mandible or the maxilla, the mean value was chosen for analysis. Both parametric independent t test (Student t test) and nonparametric t test (Satterthwaite methods) were used for comparison of the means between the two analyzed groups and then between the two analyzed implants (MKIII Groovy, X and NobelSpeedy Groovy, Y). To avoid bias, the differences in ISQ values between the different implant placement protocols at each healing time were analyzed, and both groups were divided according to the bone areas (maxilla and mandible). In addition, the Pearson correlation coefficient (Pxy) was chosen as a measure of linear association between quantitative variables (ISQ) at the time of implant placement (primary stability) and 12 weeks postintegration (secondary stability).

The current study tested the null hypothesis that there was no difference between the two surgical approaches with regard to implant stability. All statistical comparisons were conducted at the .05 level of significance.

**RESULTS**

A total of 30 healthy patients (15 women, 15 men), mean age of 46.3 years (range, 20 to 76) were enrolled in this study. A total of 61 TiUnite parallel walled implants (32 Brånemark System MKIII Groovy and 29 newly designed NobelSpeedy Groovy, Nobel Biocare), 7 to 13 mm long with a regular or wide platform diameter, were placed (26 according to the 1-stage protocol and 35 according to the 2-stage protocol).

No drop-out or deviation from the original protocol occurred in either group during the entire follow-up. The final follow-up was conducted in July 2010. Patients were followed for 6 months after prostheses delivery. The collected data were evaluated in the statistical analysis.

In both 1- and 2-stage groups, no implant was lost, thus scoring an overall success rate of 100%. A progressive bone loss with ISQ values decrease was reported in a 1-stage patient 2 weeks after implant placement (ISQ at baseline, 80; ISQ after 2 weeks, 48), with no pain nor swelling. We decided to replace the healing abutment with a cover screw. After 6 months of classic healing, the implant was successfully loaded; however, this patient was excluded from the analysis. A total of 29 patients (19 in the SG and 10 in the CG) were analyzed. Sixty implants (31 in the maxilla and 29 in the mandible) were early loaded and followed for at least 6 months in function. In the 1-stage group, nine patients received 12 implants in the maxilla, while 10 patients received 14 implants in the mandible. In the 2-stage group, two patients received implants in both the maxilla and mandible and were considered as different units, thus scoring a total of 12 patients. Nineteen implants were placed in the maxilla (five
patients), while 15 implants were positioned in the mandible (seven patients), as shown in Table 1. The age of the patients in the SG was 44.95 ± 6.00, while in the CG, it was 49.00 ± 7.85. No deviation from the original protocol was reported.

**ISQ measurements**

In the first part of the investigation, ISQ values were analyzed in the SG at implant placement (baseline) and 2, 4, 6, 8, and 12 weeks postsurgery. A high initial ISQ value was found at implant placement in both arches. Then, ISQ values commonly increased in the 2 weeks after implant placement, slightly decreased in the fourth and the sixth week (maxilla/mandible), increased again in the sixth and eighth week (maxilla/mandible), and finally tended to stabilize in both arches between the eighth and twelfth week (Fig 3).

In the second part of the study, ISQ values were analyzed to compare SG and CG in the maxilla and in the mandible at baseline and 8 and 12 weeks (Fig 4). In the maxilla, there was no significant difference for ISQ mean values between groups at baseline (SG, 74.16 ± 7.20; CG, 74.41 ± 6.01; 8 wk, SG, 77.09 ± 4.32; CG, 82.88 ± 3.63; 12 wk, SG, 77.98 ± 4.36; CG, 83.95 ± 2.33).

### Table 1: No. of implants and patients, mean age, and ISQ values for each group

<table>
<thead>
<tr>
<th></th>
<th>Implants</th>
<th>Patients</th>
<th>Age</th>
<th>ISQ baseline</th>
<th>8 wk</th>
<th>12 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG maxilla</td>
<td>12</td>
<td>9</td>
<td>50.0 ± 12.9</td>
<td>74.16 ± 7.20</td>
<td>77.09 ± 4.32</td>
<td>77.98 ± 4.36</td>
</tr>
<tr>
<td>SG mandible</td>
<td>14</td>
<td>10</td>
<td>40.4 ± 13.2</td>
<td>81.45 ± 3.63</td>
<td>82.88 ± 2.96</td>
<td>83.95 ± 2.33</td>
</tr>
<tr>
<td>CG maxilla</td>
<td>19</td>
<td>5</td>
<td>45.0 ± 13.6</td>
<td>74.41 ± 6.01</td>
<td>79.06 ± 3.93</td>
<td>79.46 ± 3.72</td>
</tr>
<tr>
<td>CG mandible</td>
<td>15</td>
<td>7</td>
<td>51.9 ± 14.4</td>
<td>81.45 ± 3.63</td>
<td>82.88 ± 2.96</td>
<td>83.95 ± 2.33</td>
</tr>
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SG, study group; CG, control group. In the CG, two patients received implants in both the maxilla and the mandible.
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± 6.01; \( P = .9489 \), after an 8-week healing period (SG, 77.09 ± 4.32; CG, 79.06 ± 3.93; \( P = .4158 \)), and after a 12-week healing period (SG, 77.98 ± 4.36; CG, 79.46 ± 3.72; \( P = .5343 \)). In the mandible, there was no significant difference for ISQ values between groups at baseline (SG, 81.45 ± 3.63; CG, 78.26 ± 2.48; \( P = .0634 \)) or after an 8-week healing period (SG, 82.88 ± 2.96; CG, 80.52 ± 5.28; \( P = .2560 \)). Instead, there was a significant difference after a 12-week healing period (SG, 83.95 ± 2.33; CG, 80.09 ± 4.11; \( P = .0261 \)).

Further, statistical analysis was performed to understand the influence of implant geometry on ISQ values. In the maxilla, NobelSpeedy Groovy yielded higher ISQ values when compared to Brånemark System MKIII Groovy. There was a statistically significant difference between the two implants in both groups at baseline (CG, 81.00 ± 1.41 and 70.33 ± 2.51, \( P = .0132 \); SG, 81.33 ± 4.61 and 70.66 ± 5.24, \( P = .0207 \)), as depicted in Fig 5. No statistically significant difference was found between the two implants after an 8-week healing period (\( P = .6123 \)) or after a 12-week healing period (\( P = .3834 \)) in the 2-stage group. There was a statistically significant difference in the 1-stage group during healing (\( P = .0243 \) after 8 weeks and \( P = .0211 \) after 12 weeks). In the mandible, similar ISQ values were found in both NobelSpeedy Groovy and Brånemark System MKIII Groovy. There was no statistically significant difference between the two implant types at each healing time for both groups, as shown in Fig 6. In addition, the Pearson correlation coefficient has been used for each utilized implant between baseline and 12 weeks. In the maxilla, similar \( P \) values were found, while in the mandible, MKIII Groovy showed a stronger correlation in the SG \( (P = .9959) \) than in the CG \( (P = .3054) \), while NobelSpeedy Groovy exhibited a weak correlation in both the SG \( (P = .4181) \) and the CG \( (P = .4525) \).

Regarding implant survival, no implant failed between surgical placement and the end of the study, gaining an overall survival rate of 100%. Intraoral radiographs at the end of the follow-up showed no radiolucency or fracture, and no biomechanic or biologic complication occurred in any group. However, in a drop-out 1-stage patient, we reported a decrease of the ISQ value 2 weeks after surgery (ISQ at baseline, 80; ISQ at 2 weeks, 48), and she was excluded from the analysis. This young nonsmoking woman had been previously treated for a localized aggressive periodontitis. The computed tomography (CT) scan analysis performed by the NobelGuide software (Nobel Biocare) showed a low Hounsfield value in the planned implant site. Nevertheless, this complication resulted in implant integration and success, thus scoring an overall success rate of 96.67%. Moreover, in the CG, 3 nonsymptomatic slight exposures of the cover screw occurred without further complications.
DISCUSSION

The present trial was designed to evaluate if the classical 2-stage implant placement can be considered a prerequisite for osseointegration. In addition, the primary and secondary stability of two implant designs were evaluated. The presented data cover a minimum follow-up period of 6 months after prosthesis delivery. This prospective clinical trial revealed no clinically or statistically significant difference for implants or prosthesis failures and ISQ values between 1- and 2-stage groups at every follow-up.

The main limitations of the current study were the different sizes of the two analyzed groups. To reduce the influence of the different sample size of the two groups, the means were compared by a nonparametric test (Satterthwaite methods). In addition, other limitations of the current study were the small sample size and the short follow-up period. However, a 6-month follow-up period is effective to fulfill the aim of the present study. The authors intended to evaluate the implant stability that occurs in the healing period before function. In addition, another limitation of the current trial was the use of two different implant designs, due to one of the secondary outcomes of this study. However, the utilized implants presented different macro design, but the same oxidized surface (TiUnite), and they were randomly distributed between the two groups in an approximately equal number.

To evaluate the osseointegration achievement, various biomechanic methods have been widely used. In recent years, a noninvasive method to assess implant stability has been developed on the basis of resonance frequency analysis. Previous research has shown that RFA measurements depend on the bone quality, surgical technique, implant design, and transducer orientation. Owing to its reproducibility, this technique has recently replaced previously advocated techniques for monitoring implant stability. Although propagated to represent a quantitative assessment for implant stability in clinical use, the exact nature of the bone/implant interface represented by RFA remains widely unknown. In a clinical trial, Zix et al compared dental implant stability by resonance frequency analysis and damping capacity assessment: They concluded that RFA appeared to be the more precise technique to measure implant stability. Therefore, it would be desirable to identify a normative range of implant stability values, correlated to better surgical protocols. Many previous randomized clinical trials on primary implant stability reported lower ISQ mean values, if compared to the results of this study. Sennerby sets the acceptable stability range between 55 and 85 ISQ. Huwiler reports that ISQ values of 57 to 70 represent homeostasis and implant stability. This RCT revealed similar ISQ values in both the 1- and 2-stage group. A high initial ISQ value was found at implant placement.

Fig 6 Compared NobelSpeedy Groovy and MKIII Groovy in the mandible.
in both groups, with significant differences regarding bone quality (maxilla vs mandible). These results indicate that in selected patients and with the utilized implants, the acceptable ISQ values could be considered ≥ 65 in the maxilla and ≥ 70 in the mandible at the time of implant placement. However, caution should be advised since the literature shows it is not possible to base the decision about immediate loading on only the ISQ value, since there are other parameters that have to be considered in such a decision. According to this prospective clinical trial, ISQ seemed to be influenced by primary implant stability (bone quality and implant site preparation), and implant type (design and surface). According to Han et al., there seems to be no difference regarding implant diameter. Instead, no difference was found regarding implant length (ie, ISQ 85 in shorty NobelSpeedy regular platform implants) in spite of the ISQ values reported by Sim et al. Concerning utilized implant surface, the new porous anodized surface (TiUnite, Nobel Biocare) showed a high primary stability. In the SG, both maxillary and mandibular values increased over time, though they showed evident reductions (in the fourth and sixth week, respectively), probably associated to physiologic healing periods. At every healing time, ISQ values were similar in both SG and CG (P > .05), with statistical significance only in the mandible at 12 weeks (SG, 83.95 ± 2.33; CG, 80.09 ± 4.11; P = .0261). This significant difference may be due to a lower MKIII Groovy ISQ mean increase in the CG if compared to the SG. However, at 12 weeks, in the SG, the amount of the ISQ mean values of the utilized implants (MKIII Groovy + NobelSpeedy Groovy) was higher if compared to the CG (due to a lower mean value of the MKIII Groovy implants in the CG). In spite of the statistically significant difference yielded, all reported ISQ mean values were always higher if compared to those reported in the literature. The new porous anodized surface (TiUnite) showed a high primary stability (ISQ ≥ 65 to 70) that tended to remain initially stable, and thereafter increased, due to the developing biologic stability (osseointegration). This result confirms that in the mandible of selected patients, TiUnite dental implants placed with a 1-stage approach can be
considered the gold standard. Moreover, NobelSpeedy Groovy seems to be preferable in the spongy bone (maxilla) for both implant placement protocols, because of its high insertion torque values and constantly high ISQ values. NobelSpeedy Groovy’s tapered tip allows for underprepared sites in softer bone, and thanks to its slightly tapered body, it offers a high initial stability in all bone conditions. In the authors’ opinion, MKIII Groovy is preferable in the mandible, especially for young clinicians, owing to its lower insertion torque. Indeed, a very high insertion torque could irrevocably damage the external hexagon of the implant or cause a cortical bone fracture.

Furthermore, a significant ISQ value decrease (55 or lower) indicates a potential problem and should be considered as an early warning and actions to shelter the implant might be considered (ie, submerge the implant). However, no value predictive of implant stability loss can be attributed to RFA. The only complication reported in this study occurred in a patient treated for generalised aggressive periodontitis. According to Ong et al., patients treated for periodontitis may experience more implant loss and complications around implants than nonperiodontitis ones. Due to the small sample, we cannot draw definitive conclusions, but we agree with the current evidence and affirm that patients with a history of periodontal disease are suitable for a 2-stage approach.

Considering the likely multifactorial relationship between ISQ and implant placement, the limits of this study could be the small sample and a short follow-up. However, a 6-month follow-up is effective to fulfill the aim of the present study. In addition, statistical analysis was performed using the patient as the statistical unit, and a randomization of the implant type was carried out to avoid bias. Owing to the limitations listed above, the results of the present study should be interpreted with caution. More well-designed RCTs, reported according to the CONSORT guidelines, are needed to investigate the correlation between ISQ values and implant geometry and size and their impact on the primary implant stability.

**CONCLUSION**

All ISQ values indicated high stability of NobelBiocare implants over a 12-week healing period in both 1- and 2-stage groups. Within the limitations of the present study, it was concluded that the 2-stage approach does not offer some advantages over the other. In selected patients, 1-stage technique is the gold standard to avoid the second surgical intervention and shortens treatment times. NobelSpeedy Groovy showed a higher primary anchorage, especially in the maxilla.

**REFERENCES**


