Implant Stability, Tissue Conditions, and Patient Self-Evaluation after Treatment with Osseointegrated Implants in the Posterior Mandible

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ABSTRACT

Background: Implant treatment in the posterior mandible is considered challenging because of bone resorption and the presence of the inferior alveolar nerve, which may result in the use of short implants.

Purpose: To evaluate implant stability, tissue conditions, and patient opinion after treatment with implant-supported bridges in the posterior mandible.

Materials and Methods: Thirty-four patients treated with implant-supported bridges in the posterior mandible according to a two-stage protocol were clinically and radiographically examined and interviewed after a mean functional time of 3.9 years. One hundred five Brånemark® implants (Nobel Biocare AB, Gothenburg, Sweden) were placed in premolar and molar regions to support 40 bridges. Twenty-eight implants were placed anterior to the mental foramen, and 77 implants were placed posterior to the mental foramen. Bridges were supported either by two or by three implants. After 2 to 6 years, the bridges were removed to analyze the resonance frequency of the implants with the use of a special instrument (Osstell™ instrument, Integration Diagnostics AB, Gothenburg, Sweden), and an implant stability quotient (ISQ) was recorded for each implant.

Results: One implant was lost. An ISQ range of 59 to 90 (mean, 70.05) expressed stability of fully integrated implants in the posterior mandible. Significantly higher ($p < .024$) ISQ values were found in implants in three-implant bridges when compared with implants in two-implant bridges. There were no differences in ISQ values between molars/premolars, implant types, implant widths, implant lengths, anchoring depth, or uni- or bilateral mandibular bridges. Good mucosal health in the periimplant soft tissue and minor bone resorption around the implants were observed. Patients were generally very satisfied with the treatment outcome.

Conclusions: High implant stability can be reached in the posterior mandible. The implants were more stable in three-implant bridges than in two-implant bridges. The patients were highly satisfied with the treatment, and few complications were seen.

KEY WORDS: dental implant, endosseous implant, implant stability, osseointegration, Osstell, posterior mandible, resonance frequency analyses

Osseointegrated implants were initially developed for the treatment of totally edentulous patients, and outcomes for such treatment have been extensively documented over the years.[1–5] Today osseointegrated implants are also used in patients with partial edentulism[6,7] and for replacing single teeth.[8,9] Implants in the anterior region of the mandible can take the load of a full-arch bridge construction; for this reason, installation in the posterior mandible can be avoided in totally edentulous mandibles. In mandibles with tooth loss only in the posterior region and with teeth still present in the anterior region, installation in the posterior

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TABLE 1 Number of Patients, Median Age and Number of Inserted Implants Distributed in Bridges

Gender	Number of Patients	Median Age (yr)	Age Range (years)	Number of Implants	Two-Implant Bridges	Three-Implant Bridges
Male	15	63	46–71	45	6	11
Female	19	61	43–80	60	9	14
Total	34	62	43–80	105	15	25

mandible can be considered for some patients. However, because in the posterior mandible the inferior alveolar nerve is present in the installation area, risk of nerve injury is a significant factor because of the surgery.[10]

Given sufficient bone volume superior to the nerve and provided that bone quality is good, installation is possible with conventional implant techniques. There are, however, situations when compromised bone volume and quality do not permit implant installation with conventional implant techniques. In cases with more severe bone resorption, the shifting of the inferior alveolar nerve by transposition or lateralization of the nerve has been suggested.[11–15] Problems with paresthesia of the mental nerve, however, have been reported with both of these procedures.[11–15] In such patients the length and direction of inserted implants must be adjusted to the underlying conditions. The use of shorter but wider implants superior to the inferior alveolar canal also allows implant installation in some of these cases.[16] However, short implants are anchored only in the superior cortex, which may compromise the load-bearing capacity. Furthermore, short implants are reported to fail more frequently than longer ones.[10,16,17] To overcome this problem, some surgeons prefer to place implants in a somewhat angulated position to avoid contact with the nerve.[18,19] Such a procedure allows the use of longer implants that can be anchored in both the superior and inferior lingual cortices. In our clinic, the Department of Oral and Maxillofacial Surgery, Central Hospital in Västerås, direct installation in the posterior mandible without bone grafting or nerve transposition has been the method of choice during the past decade. However, little is known about osseointegration in the posterior mandible after such surgical procedures. The introduction of resonance frequency analysis (RFA) has enabled us to measure implant stability and thus assess the quality of osseointegration that is possible.[20–23]

The purposes of this study were to evaluate the implant stability and tissue conditions associated with implant treatment in the posterior mandible and to assess the outcome of the treatment, using a patient evaluation instrument.

MATERIALS AND METHODS

Thirty-four patients (15 males and 19 females) with a median age of 62 years (range, 43 to 80 years) agreed to take part in this study. All were treated for posterior mandibular edentulism with implant-supported bridges at the Department of Oral and Maxillofacial Surgery at Central Hospital in Västerås during the years 1996 to 2000 (Table 1). The implant installations were performed posterior to the mandibular canine tooth, in the area of the inferior alveolar nerve. In total, 105 implants (Brånemark®, Nobel Biocare AB, Gothenburg, Sweden) were installed. All patients were treated according to Brånemark's two-stage surgery method,[6,7,24] and all implants were placed in premolar or molar regions, anterior, superior, or lingual to the mandibular canal. Of the 105 implants, 28 were inserted superior to the mental foramen at the height of the alveolus but angulated in a direction anterior to the foramen, 20 were placed lingual to the mandibular canal, and 57 were

TABLE 2 Type and Length of Implants placed in 34 Patients Treated for Single or Partial Edentulism in the Posterior Mandible

Length	Standard (RP + WP)	Mk II (RP + WP)	Mk III (RP)	Total
All lengths	54	45	6	105
8.5mm	—	2	5	7
10.0mm	30	22	1	53
12.0mm	14	7	—	21
13.0mm	8	6	—	14
15.0mm	1	7	—	8
18.0mm	1	1	—	2

RP = regular platform, WP = wide platform.

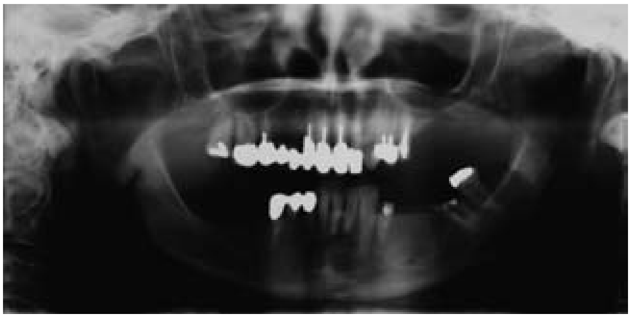

Figure 1 Panoramic radiograph taken 6 months before implant installation.

Figure 2 Panoramic radiograph taken 6 months after bridge insertion.

placed superior to the mandibular canal. Wide-platform (WP) implants were exclusively used superior to the mandibular canal. The types and lengths of implants used are summarized in Table 2. Neither bone grafting nor nerve transposition was used. Oral antibiotics were administered to all patients over a 1-week period after surgery, starting 1 hour before surgery.

After second-stage surgery (3 to 6 months after implant installation), implant-supported bridges were constructed. Bridges were implant supported only and were not combined with any tooth support (Figures 1–4).

Data on the patients and on the distribution of implants over bridges supported on two and three implants are shown in Table 1. The patients were followed up at 1 year post surgery, according to our clinical routines, and each patient agreed to visit the clinic for a voluntary registration of tissue conditions and implant stability 2 to 6 years after implant installation. Approval from the ethics committee was obtained.

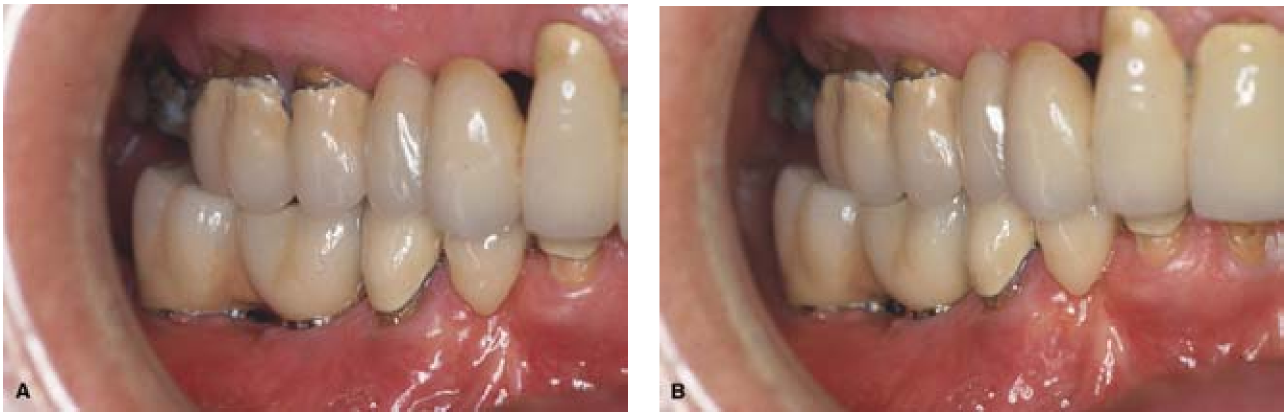

Figure 3 *A* and *B*, Implant-supported bridge on the right side of the mandible.

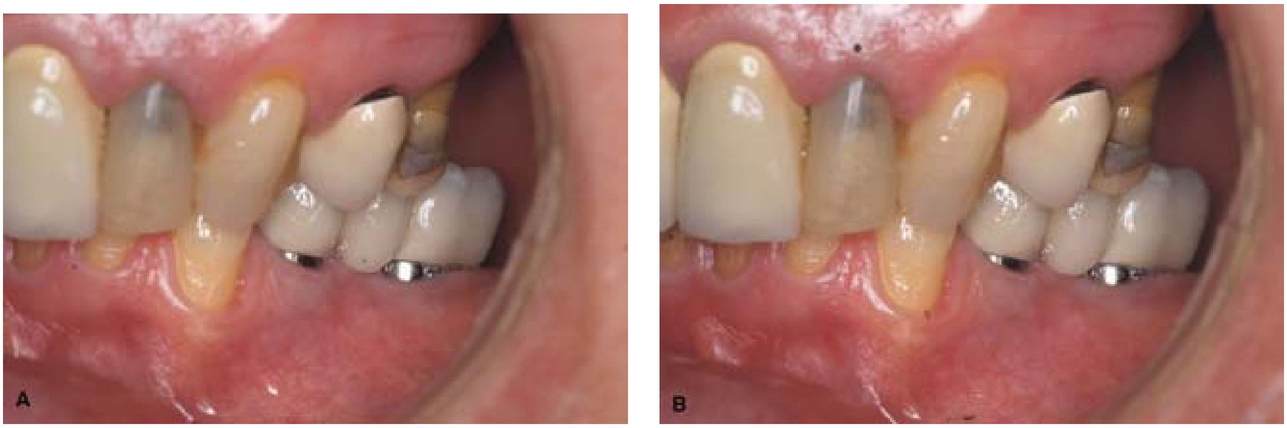

Figure 4 *A* and *B*, Implant-supported bridge on the left side of the mandible.

TABLE 3 Implant Stability Quotient Values (mean ± SD) in a Sample of 104 Fixtures According to Implant Features and Characteristics

Implant Feature	No. (%)	ISQ (Mean ± SD)	*p* Value
No. of implants in bridge			
Two	30 (28.8)	67.9 ± 5.25	0.024*
Three	74 (71.2)	70.9 ± 6.41	
Region Molar/ Premolars			
Molar	64 (61.5)	70.1 ± 6.03	0.911
Premolar	40 (38.5)	70.0 ± 6.62	
Type of implant			
Standard	55 (52.9)	70.2 ± 6.93	0.104
Mk II	43 (41.3)	69.3 ± 5.22	
Mk III	6 (5.8)	75.2 ± 4.10	
Platform			
Regular platform (RP)	73 (70.2)	70.8 ± 5.82	0.060
Wide platform (WP)	31 (29.8)	68.3 ± 6.89	
Implant Length (mm)			
8.5	7 (6.7)	70.9 ± 7.40	0.439
10.0	52 (50.0)	70.8 ± 5.55	
12.0	21 (20.2)	69.2 ± 5.70	
13.0	14 (13.5)	67.2 ± 5.70	
15.0	8 (7.7)	71.8 ± 5.57	
18.0	2 (1.9)	70.5 ± 9.19	
Marginal bone resorption (no. of threads)			
0	57 (54.8)	70.2 ± 5.98	0.707
1	36 (34.6)	69.6 ± 6.66	
2–3	11 (10.6)	71.4 ± 6.45	
Anchoring Level			
Inferior to nerve	28 (26.9)	70.5 ± 6.68	0.655
At nerve level	20 (19.2)	68.9 ± 4.39	
Superior to nerve	56 (53.8)	70.3 ± 6.60	
Side of patient			
Unilateral	77 (74.1)	70.3 ± 6.40	0.490
Bilateral	27 (25.9)	69.4 ± 5.76	

ISQ = implant stability quotient.
*Significant *p* - value.

Bridges were removed, and the following variables were registered at the patient's checkup:

1. Implant stability was measured with a resonance frequency analyzer (Osstell™, Integration Diagnostics AB, Sävedalen, Sweden) and expressed as an implant stability quotient (ISQ). Comparisons of ISQ values were made between the following grouped variables:
   a. Region (molar or premolar)
   b. Bridge type (two- or three-implant bridge)
   c. Implant type (Brånemark Standard, Mark II, or Mark III)
   d. Implant width (wide platform or regular platform)
   e. Implant length (millimeters)
   f. Marginal bone resorption (number of threads)
   g. Anchoring depth (inferior, superior, or at nerve level as seen with radiography)
   h. Bridge rehabilitation (one- or two-sided)
2. Neurosensory alteration was registered, with special focus on the alveolar inferior nerve (mental

branch) and lingual nerve, by asking the patient to give a "yes" or "no" response.

3. Bleeding tendency from the gingival margin around the exposed implants was registered as a modified sulcus bleeding index (measured as bleeding or no bleeding).[25]
4. Marginal bone loss was measured on radiographs taken with a paralleling technique and an Eggen film holder (Eggen X-ray AS, Germany).[26] Radiographic bone loss was defined as vertical bone level shift and was measured in relation to the most superior thread of the implant.
5. A questionnaire was completed by patients to assess treatment outcome.

Results are presented as mean ISQ values ± standard deviation. Levene's test for homogeneity of variance was used to test the distribution of ISQ values. Since ISQ values were found to be normally distributed, the *t*-test was applied to test any differences in ISQ values in the case of two independent groups, and an analysis of variance (ANOVA) for multiple comparisons was made using the Bonferroni post hoc test. A probability level of $p < .05$ was considered significant. Statistical software (SPSS® 11.5, SPSS Inc., Chicago, IL, USA) was used for analysis.

RESULTS

Neurosensory Alteration and Periimplant Tissue Conditions

Thirty-three patients showed no signs of neurosensory disturbances. One patient reported slight unilateral sensory disturbance of the lower lip, which had been persistent since implant installation 3 years before follow-up. On pressure no bleeding from the periimplant mucosa was observed. Most implants (89.5%) showed a marginal bone shift of one thread or less. Eleven implants (10.6%) showed marginal bone loss of more than one thread. One implant was mobile and hence was removed; however, this loss did not result in removal of the bridge, which could still be fully supported by the remaining two implants. Thus all 40 bridges survived.

Implant Stability

After a mean functional period of 3.9 years (range, 2 to 6 years), 104 implants were found to be clinically stable. These implants had a mean ISQ of 70.05 ± 6.07 (range, 59 to 90). Table 3 presents the ISQ values according to the number of implants in bridges, region, implant type, platform width, implant length, marginal bone resorption, anchoring depth, and side of patient. Significantly higher ISQ values were found for implants in three-implant bridges as compared with implants in two-implant bridges. No difference was observed in ISQ values between implants placed in molar or premolar regions. The type of implant had no significant influence on the ISQ values. There was a tendency, although not significant, for WP implants to have lower ISQ values as compared with RP implants. Eight WP implants of an older type without flange contributed to this finding. In comparison with the modern WP implants with flange, whose ISQ values ranged from 60 to 90, all eight of the older implants

TABLE 4 Responses of the 34 Patients to the Self-Evaluation Questionnaire at the Checkup and Examination Visit

	Answer	
Question	Yes	No
Did the treatment with implant crown/bridge satisfy your expectations?	34	
If necessary, would you consider undergoing the same type of treatment again?	33	1
Do you find oral hygiene more difficult around the implant crown than around your own teeth?	29	5
Are you satisfied with your ability to chew/bite?	34	
Are you satisfied with the form and color of your crowns?	32	2
Would you recommend this treatment to any one you know?	34	
Was it worth the money and time you spent for this treatment?	34	

showed lower values (range, 59 to 65 ISQ). The former is the type that is used today, and the transducer was designed for this new type. The ISQ values were not correlated to variation in lengths of implants, and the marginal bone level had no significant impact on the ISQ value. Anchoring depth also had no influence on the ISQ value. Implants anchored superior to, inferior to, or at nerve level showed similar values. Finally, no difference in ISQ values was noted between patients with unilateral bridges and those with bilateral bridges.

Patients' Evaluations

Patients' responses to the treatment are summarized in Table 4. All patients reported that the treatment satisfied their expectations. The self-questionnaires also indicated that all patients were fully satisfied with the function of the bridges and that they would recommend the treatment to others. Furthermore, all patients reported that the treatment was well worth the expense and trouble. All but one patient would repeat the treatment again if necessary. Five patients found it more difficult to maintain oral hygiene around their implants than around their natural teeth, and two patients were dissatisfied with the color of their crowns.

DISCUSSION

Osseointegrated implant treatment is a well-documented method that shows high success rates in the treatment of totally edentulous mandibles,[27,28] yet reports of cases in which the method has been used to treat partial edentulism in the posterior mandible are scarce.[11,29] The results of the present follow-up study indicate that implant installation in the posterior mandible without bone grafting or nerve transposition is a successful treatment method that achieves a high degree of implant stability with few complications. Furthermore, the patient evaluation instrument indicates that the patients were generally very satisfied with the treatment.

Clinical follow-up studies present special problems, especially when patients are asked to volunteer to have their bridges removed for registration. Not surprisingly, some patients were unwilling to take part in such examinations. Although only one implant was lost and all bridges survived in the patients who registered at our clinic, other results might have been seen in those patients who refused to allow the removal and registration of their bridges. We have therefore abstained from deriving a general success rate from this material.

Implant rehabilitation in the posterior edentulous mandible is more challenging than in totally edentulous jaws because of bone properties and anatomic limitations.[29] The cortical bone of the alveolar crest in the posterior mandible is thin in many patients, and the cancellous bone frequently has an exceedingly thin trabecular pattern, making it less suitable for implant placement in many patients.[30] Other factors causing problems in installation are bone resorption and the presence of the inferior alveolar nerve. Bone grafting is seldom used in the mandible although local onlay grafts can be used in the mandible to increase the width of the crest. Bone grafting was not used in this study. Transposition and lateralization of the inferior alveolar nerve in the installation area have been reported to allow the installation of longer implants and to avoid interference with the nerve.[11,13,14] However, the surgical procedure itself may cause significant nerve injuries. Neither lateralization nor transposition of the inferior alveolar nerve was carried out in our patients. Instead, the majority of the implants were placed anterior, lingual, or superior to the mandibular canal. Fixture placement posterior to the foramina is, as mentioned previously, associated with a certain risk of trauma to the inferior alveolar nerve,[10] the location of which is sometimes difficult to identify.[31,32] Klinge and colleagues[31] showed that computed tomography (CT) provides the most accurate localization of the mandibular canal and therefore is probably the best method for the preoperative planning of implant surgery involving the area close to the mandibular canal. In our study only panoramic radiography and conventional tomography were used to assess the alveolar height superior to the mandibular canal. Because only one patient reported slight unilateral sensory disturbances of the lower lip at the checkup visit, it can be assumed that careful planning with these methods, in combination with clinical experience, might be sufficient; however, a more detailed examination can be performed with CT.

WP implants allow an increased surface area for osseointegration with a shorter implant. For this reason WP implants may be suitable for installation in posterior regions to avoid transposition of the inferior alveolar nerve. However, the faciolingual width of the crest must be sufficient for installation of a wide implant. In many of our patients short and wide implants were used superior to the canal and were combined in the bridge with a longer implant, usually in the first premolar position, angulated anterior to the mental foramen and cortically anchored.

The stability of implants in this study was measured by using the method of RFA, which has been shown to be reliable, objective, and highly valid.[20–22] This method is an important diagnostic tool for helping the clinician evaluate implant stability and predict the prognosis of implants. Earlier measurements of implant stability with this technique were expressed in hertz,[20–22] and more recently the ISQ value was introduced. The stability measurements in our study showed a mean ISQ of 70.05, with a range of 59 to 90. Values in these ranges indicate osseointegrated implants with high implant stability. Balleri and colleagues reported that a mean ISQ of 72.8 with a range of 62 to 82 may describe the stability of a fully integrated implant in the mandible.[23] The implants in our study reached a high stability after healing and adaptation during a 2- to 6-year period. We believe that such a long healing time should be considered when interpreting the results.

The finding that implants in three-implant bridges evidenced higher ISQ values than implants in two-implant bridges indicates that bridges constructed on two implants may run a higher risk for loss. This fact has been pointed out before, by Rangert and colleagues, who stated that from a biomechanical standpoint (ie, bending and loading forces), supporting a prosthesis on three implants is much better than supporting it on two implants.[33]

Increasing the number of implants apparently results in higher ISQ values for the individual implants in the bridge. This study suggests that whenever possible, the surgeon should aim at placing three rather than two implants in the posterior mandibular region. The region where the implant is placed is of little importance. Furthermore, implant length and anchoring depth do not seem to have much significance. Apparently, it is more important to achieve primary stability with at least three implants. A short additional third implant superior to the nerve may be the best alternative in surgical situations in which installations of only two implants primarily are considered.

We found that the length of the implant has little impact on the ISQ value, a finding consistent with Balleri and colleagues, who suggested that short implants reach the same high stability reached by long implants.[23] Because the ISQ value was similar for premolar and molar regions, our study also demonstrated that the position of the implant is not of importance after healing and adaptation. Furthermore, after healing and adaptation it does not seem to matter whether or not the implant is anchored deeply in the mandible or which type of implant is used. Moreover, marginal bone resorption around the implant does not result in significantly lower ISQ values. This is obviously an effect of the fact that our measurements were made after 2 to 6 years of healing and adaptation. However, the results of our study should not be interpreted to mean that these factors are not crucial for the short-term perspective of healing. Achieving a primary stability at the time of surgery is important and may motivate the use of long and wide implants. Furthermore, it may be necessary to use a long implant to reach primary stability during surgery. Angulating the implant slightly may also be necessary in certain situations, both to achieve cortical anchoring and to avoid contact with the inferior alveolar nerve. In addition, the quality of bone may have an influence on the surgeon's selection of the type of implant. All these steps are necessary to achieve primary stability during surgery. However, given that primary stability is achieved during surgery, the implant's length, type, position, and anchoring depth seem to be of similar importance after healing and adaptation have taken place. If marginal bone resorption occurs, the ISQ value does not change, at least when the resorption is limited to two or three threads.

Healthy tissue conditions were found in all patients 2 to 6 years after insertion of the implants, suggesting that these partially edentulous patients generally were capable of maintaining good oral hygiene around their implants. However, it should be noted that five patients (15%) in our study reported that oral hygiene procedures were more difficult to perform around implant constructions as compared with their own teeth.

The self-evaluation questionnaires indicated that patients were generally satisfied with the outcome of the treatment, supporting the notion that this treatment method is a valuable tool in the rehabilitation of patients who have lost teeth in the posterior mandibular regions.

CONCLUSIONS

The present results clearly show that implant treatment in the edentulous posterior mandible without bone grafting and without repositioning of the inferior alveolar nerve can result in high implant stability after healing and adaptation. For reasons of stability, it may be desirable to install three implants instead of two at the time of surgery whenever possible. The patients in our study were highly satisfied with the treatment, and few complications were seen.

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