Influence of Bicortical or Monocortical Anchorage on Maxillary Implant Stability: A 15-Year Retrospective Study of Brånemark System Implants

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The present study evaluated implant survival and marginal bone loss in maxillae over a 15-year follow-up period as a function of either monocortical or bicortical implant anchorage. Of 207 standard Brånemark implants (10 mm in length) followed, 110 implants were judged to be monocortically anchored and 97 as bicortically anchored. The bicortically anchored implants failed nearly 4 times more often than the monocortical ones. Implant fractures accounted for over 80% of the observed failures and were found to affect the bicortical group almost 3 times more often. As tentative explanations, induction of increased stress and bending forces resulting from possible prosthetic misfit, presence of unfavorable arch relationships, or high occlusal tables in combination with bicortically anchored implants have been suggested, all indicating an overambitious fixation of the bicortical anchorage. Total marginal bone loss was low over the 15-year period and close to identical for the 2 groups, suggesting that the mode of cortical anchorage did not have any clinically significant influence on marginal bone remodeling. (Int J Oral Maxillofac Implants 2000;15:103–110)

Key words: *biomechanics, Brånemark System, cortical anchorage, titanium oral implant, treatment result*

The Brånemark implant system has been used in clinical practice since 1965 and has over the years proven to be a successful and reliable treatment procedure.[1,2] From the clinical start in 1965 and up to 1971 (referred to as the development period), most changes in the system related to implant design, instrumentation, and surgical technique took place.[3] Thereafter, a more or less standardized protocol has been used,[4] the principles of which can be summarized as follows:

1. A screw-type implant made of commercially pure titanium is used.
2. An atraumatic 2-stage surgical procedure is advocated.
3. Controlled implant loading through a passively fitting prosthetic restoration is recommended.

Through the years several authors have recommended biocortical implant anchorage.[5–8] Still, there are few clinical studies that specifically investigate the relevance of this issue, even if Brånemark et al,[9] Hessling et al,[10] and Jensen et al[11] have reported favorable success data for nasal- and sinus-penetrating implants as well as fewer implant failures for bicortically anchored maxillary and mandibular Brånemark implants. Perforation of the maxillary

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sinus and the nasal cavity may create an increased risk factor for infections, but such a side effect has not been reported.[9–12]

In an experimental study in rabbit tibiae, in which implants were penetrating either 1 or 2 cortical layers, Ivanoff et al[13] showed significantly higher removal torque and bone-to-implant contact for bicortical implants after 6 and 12 weeks. Consequently, it seems favorable to engage as much cortical bone as possible when placing oral implants. However, in a finite element method (FEM) study by Van Oosterwyck et al[14] the effect of bicortical versus monocortical anchorage was evaluated, and bicortical fixation reduced the stress and strain levels along the entire implant length by about 30% compared to the monocortical situation. However, the decrease was substantial only in a situation with poor bone quality, and therefore the authors questioned the relevance of bicortical fixation where good density bone exists.

In another FEM study, Rieger et al[15] found that stress concentrations were located around the cervical region and apex of the implant. Further, the authors noted little stress transfer along the middle portion of the implant and were therefore concerned about poor stress transfer to that area, which they suggested could result in bone atrophy. The same stress pattern was also previously reported by Haraldsson[16] in a photoelastic study (Fig 1). However, this theory of stress distribution has not been supported by any clinical studies, as corticalization has instead been seen at the interface of clinically loaded implants,[17] together with increased peri-implant bone density[18] being exemplified schematically in Fig 2. There also seems to be a difference in load distribution according to bone qualities. Clelland et al[19] showed in an FEM study that maximum stress and strain were concentrated around the implant apex in a cancellous bone model, whereas the greatest stress concentration occurred in the crestal cortical bone in a combined cortical/cancellous situation. However, a thicker cortical layer reduced the stress level. In a bicortical anchorage situation where the amount of peri-implant cortical bone is increased (Fig 3), this kind of stress pattern may result in disuse atrophy in the marginal cortex, as described in Fig 4.

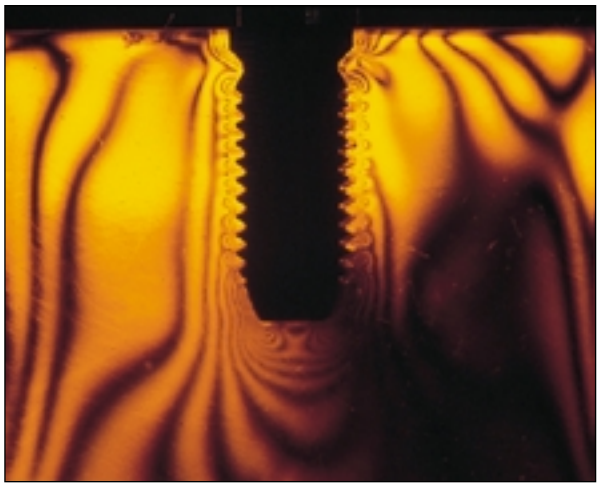

Fig 1 Photoelastic model of a loaded Brånemark System implant, showing the stress distribution to be located around the cervical region and apex of the implant.

Fig 2 Schematic drawing showing corticalization around an implant subjected to functional loading.

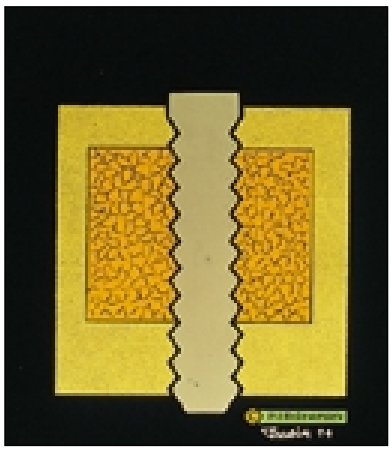

Fig 3 Schematic drawing of bicortical anchorage, indicating the rigid fixation that such an implant may have compared to the monocortical anchorage situation.

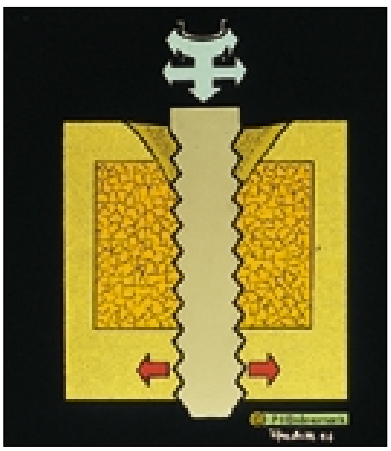

Fig 4 Schematic drawing indicating that an increased amount of cortical bone in the apical region of an implant may result in disuse atrophy in the marginal cortex because of stress concentrations in the apical region of the implant.

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The aim of the present investigation was to evaluate, over a 15-year follow-up period, implant survival and marginal bone loss in maxillae as a function of either monocortical or bicortical implant stabilization.

MATERIALS AND METHODS

The study was based on retrospective patient material obtained from the Department of Jaw Reconstructive Surgery, Faculty of Odontology, Göteborg University, Göteborg, Sweden. During the period from 1977 to 1983, 351 patients were provided with Brånemark System implants (Nobel Biocare, Göteborg, Sweden). Of the total patient material, an investigation sample was created based on the following criteria: the patients were edentulous in the maxilla at the time of implant surgery and provided solely with standard Brånemark implants, 10 mm long, independent of arch shape and bone quality. Grafted patients and those treated with other implant lengths and/or designs were all excluded. As a result of this selection, a group of 20 females and 17 males, having a mean age of 50 years (range 31 to 73 years), became available for the current investigation. The selected patients are a part of the total patient material (277 maxillae/482 mandibles) treated at the above-mentioned clinic during the years 1965 to 1987, the results of which have been presented by Adell et al.[20]

The investigation, based on findings in the patients' records, included both clinical and radiographic information obtained at baseline (presurgical assessment); abutment connection; at the time of prosthesis placement (+ 3 months); and at 1 year (± 6 months), 5 years (± 1 year), 10 years (± 1 year), and 15 years (± 1 year) of follow-up. Jawbone quality and quantity were retrospectively classified from panoramic radiographs and lateral cephalograms according to Lekholm and Zarb.[21] A majority of the 37 maxillae could be categorized as having bone quality group 3 and shape groups C or D (Table 1).

At implant placement, the 37 arches had been provided with 218 implants. Of these, 6 were excluded, since they were not uncovered during the follow-up period, while another 5 implants in 4 patients failed before or at abutment surgery, giving a total of 207 implants for the present analysis (Table 1). These latter implants were radiographically classified (using panoramic images obtained at abutment connection) as either monocortically or bicortically anchored, ie, the "apical" part of the implant did or did not engage the anterior or inferior border of the maxillary sinus or the floor of the nasal cavity. Initially, 1 investigator performed these analyses. However, in 36 instances it was difficult to classify the implants, and therefore 3 investigators assessed these cases. Nineteen of the implants were thereby judged as monocortical and 17 as bicortical, giving a total of 110 monocortical implants and 97 bicortical implants (Table 1). An equal distribution of the number of patients with respect to the ratio of monocortically or bicortically placed implants within the arches was found (Table 2). To evaluate the reproducibility of the performed grading of the implant anchorage, a re-evaluation was carried out 6 months later. One implant per patient was randomly chosen by using a random table, and selected implants were again classified by the first investigator, revealing a match of 35/37 (94.6%).

Table 1 Frequencies of Placed and Failed Implants with Regard to Bone Quality, Bone Quantity,* and Anchorage

	Monocortical		Bicortical	
	Placed	Failed	Placed	Failed
Bone quality				
1	0	—	0	—
2	0	—	0	—
3	104	4	86	14
4	6	0	11	0
Bone quantity				
A	0	—	0	—
B	32	0	11	0
C	54	1	35	4
D	24	3	51	10
E	0	—	0	—

*Graded according to Lekholm and Zarb.[21]

Implant survival was judged from patient records and intraoral radiographs, and when indications of a loose implant had been found, such an implant was usually tested for stability after the prosthetic restoration was removed. Marginal bone level was measured on the intraoral radiographs in relation to a fixed point on the implant,[3] defined as the edge between the conical and cylindric parts of the implant head (0.8 mm below the abutment/implant junction). The radiographic assessments were performed by 1 investigator, using a magnifying lens ×7, at the mesial and distal implant surfaces and to the nearest 0.1 mm, whereafter a mean value was calculated per implant.

Initially, 37 patients were included. Because of various reasons (death, moving out of the area, lack of interest), however, patients dropped out during the follow-up period, leaving 30 patients after 5 years, 23 after 10 years, and 16 after 15 years.

For recorded data, mean values, standard deviations, and frequency distributions were calculated. Cumulative survival rates (CSR) were determined for the total number of implants (including the 5

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Table 2 Distribution of Patients/Implants with Respect to the Ratio of Mono- or Bicortically Anchored Implants Within the Arches

No. of monocortically anchored implants	No. of patients	No. of implants	No. of patients with failures	No. of failed implants
0 of 4, 5, or 6	5	25	0	0
1 of 5, 6, or 7	4	23	3	16
2 of 4, 5, or 6	3	16	1	1
3 of 4, 5, 6, or 7	10	57	0	0
4 of 5 or 6	5	29	1	1
5 of 6	6	36	0	0
6 of 7	1	7	0	0
All monocortical	3	14	0	0
Total	37	207	5	18

implants lost before or at abutment connection), as well as for the mono- and bicortical groups, respectively, using life table analysis.[22]

RESULTS

Implant Survival

Of the 207 loaded and followed implants, a total of 18 implants (8.7%) failed during the follow-up period. Taking into account the 5 implants lost before or at abutment connection (not possible to classify as mono- or bicortical), a total CSR of 88.7% was found after 15 years. The corresponding values regarding the mono- or bicortically anchored groups were 96.2% and 84.8%, respectively (Table 3). The failures occurred in bone quality group 3 and mainly in arch shape group D (Table 1). Observed failures occurred in 5 patients, 2 of whom experienced total implant failures and accounted for 12 of the 18 implant losses observed (Table 2). Of the 4 patients who initially had lost 5 unclassified implants (lost before or at abutment surgery), 2 later experienced further implant failures. However, no specific characteristics regarding general health, smoking habits, or other addictions were noted in the records for these patients.

The monocortical group showed 4 failures (3.6%) of the 110 placed implants (Table 3), all 4 of which fractured. Two of these were possible to repair, however, and could be reused as anchorage units, while the other 2 had to be explanted. In the bicortical group, 14 failures (14.4%) were found of the 97 originally placed and followed implants (Table 3). Eleven of these failures resulted from implant fractures, of which 6 were removed (2 because of later loss of integration), whereas 5 implants could be repaired and reused. The remaining 3 implants failed because of loss of integration (all in 1 patient). Sixteen of the 18 failures occurred in 3 patients, who had a high ratio of bicortically anchored implants within their arches (Table 2).

Marginal Bone Loss

Changes in mean marginal bone level around the implants, observed during the 15-year follow-up period, are presented in Table 4. Since radiographs were not available for all implants at all time intervals, the number of observations did not match the total number of implants investigated at every observation time period. As a mean, the marginal bone level changed less than 1.0 mm over the entire follow-up period, independent of the type of implant anchorage.

DISCUSSION

The aim of the present study was to evaluate whether mono- or bicortical anchorage of oral implants, observed during a 15-year follow-up period, had any influence on implant survival and marginal bone loss. It was found that the bicortically anchored implants failed nearly 4 times more often than the monocortical ones, whereas no difference in marginal bone loss could be observed between the 2 groups. Fifteen of the 18 failures observed involved implant fractures, and the fracture rate was 3 times higher in the bicortical group than in the monocortical group. This is a higher figure than what has been presented by others,[23–26] but it is within the same range as was reported in a

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Table 3 Life Table Analysis Showing Cumulative Implant Survival Rates (CSR) for Implants with Either Mono- or Bicortical Anchorage, as Well as for the Total Implant Material (Including 5 Implants Lost Before or at Abutment Surgery)

Type of anchorage	Followed	Failed	Withdrawn	CSR
Monocortical anchorage				
Placement to loading	110	0	0	100%
Loading to 1 year	110	1	0	99.1%
1 to 5 years	109	2	20	97.3%
5 to 10 years	87	1	15	96.2%
10 to 15 years	71	0	30	96.2%
15 years	41	—	—	—
Bicortical anchorage				
Placement to loading	97	0	0	100%
Loading to 1 year	97	5	0	94.8%
1 to 5 years	92	7	11	87.6%
5 to 10 years	74	1	20	86.4%
10 to 15 years	53	1	16	84.8%
15 years	36	—	—	—
Total implant material				
Placement to loading	212	5	0	97.6%
Loading to 1 year	207	6	0	94.8%
1 to 5 years	201	9	31	90.6%
5 to 10 years	161	2	35	89.4%
10 to 15 years	124	1	46	88.7%
15 years	77	—	—	—

study by Adell et al.[20] The overall survival rate was about 89%, which exceeds the outcome of the earlier study by Adell et al.[20] However, the 15-year result reported in that study (76%) was calculated on routine group 1, patients treated between 1971 and 1975. The present result corresponds instead with the 5- and 10-year outcomes of routine group 2 (treated between 1976 and 1981),[20] a period that better conforms with the currently studied period; however, now followed longer. Three implants, all found in 1 patient, were removed because of loss of integration, and 2 patients accounted for ⅓ of all implant failures, which gives support to an earlier observation that implant failures tend to cluster in certain individuals.[23,27] However, because of this phenomenon it is difficult to judge how the failures were related to type of anchorage. Variables such as smoking, opposing occlusion, cantilever length, and parafunction, all conditions that also could have influenced the implant survival, were not evaluated in the present report, as they were not recorded at the time of treatment.

The present patient sample was rather small, and the drop-out level was relatively high. In years 10 to 15, 35% of the monocortical and 45% of the bicortical implants were lost to follow-up. In many situations, the patients had been referred for treatment from all over Sweden, and after some years, several of them had returned to referring clinics for continuous

Table 4 Mean Distance (mm) Between Reference Point and Bone Level for Different Time Periods with Respect to Mono- or Bicortical Bone Anchorage

Time point	Monocortical	Bicortical	Total
Loading			
No. of implants	89	66	155
Mean distance	1.2	1.4	1.3
Standard deviation	0.9	1.0	0.9
1 year			
No. of implants	75	70	145
Mean distance	1.4	1.5	1.5
Standard deviation	0.6	0.8	0.7
5 years			
No. of implants	50	55	105
Mean distance	1.7	1.5	1.6
Standard deviation	0.9	0.9	0.9
10 years			
No. of implants	66	50	116
Mean distance	1.7	1.7	1.7
Standard deviation	0.9	1.0	0.9
15 years			
No. of implants	28	32	60
Mean distance	2.0	2.2	2.1
Standard deviation	1.1	1.0	1.1

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check-ups. One might consider the possibility of selection bias, since the study was based entirely on existing records. Patients experiencing failures may be more prone to seek treatment and therefore be subjected to a more thorough follow-up. These limitations make it difficult to determine how anchorage is related to implant failure, and, therefore, obtained results must be interpreted cautiously. There is probably no corresponding patient material available where only one standard implant length (10 mm) had been used and followed up for the same length of time, independent of arch shape and quality. Consequently, the investigated material is somewhat unique. The radiographic classification of the mode of implant anchorage is afflicted with severe weaknesses. The panoramic image can only give information about the vertical relationship between an implant and the anatomic cortical border (nasal cavity, maxillary sinus), whereas it is impossible to judge whether the implant will engage the palatal and/or facial compact bone lamella. Theoretically, bicortical implants would be more prone to engage the palatal and/or facial lamella because of the higher degree of resorption (Table 1), but it cannot be excluded that the same could have taken place also for the monocortical implants. To be able to properly evaluate this aspect, it would have been necessary to perform some kind of tomography. However, it seems unacceptable from an ethical point of view to expose the patients to additional doses of radiation to obtain that kind of information.

The main cause of implant failure was fracture and not loss of integration. This finding may indicate that the implants had been subjected to excessive stress, with subsequent material fatigue. An in vivo analysis of fractured implants, combined with an in vitro strength test, has demonstrated that implant fractures will occur as the result of component fatigue.[28] One explanation for the high fracture rate observed in this study could be that, during the time period studied (1977 to 1983), prosthetic misfit was a problem,[3,7] which may have induced unfavorable stress and tension in the system.[29] The current results further support such an explanation, as fractures were observed in both groups. Lack of passive fit of a fixed prosthesis may be more of a problem if implants are bicortically anchored, which a recent study has also confirmed.[30] The observed lower implant fracture rates reported in the above-referenced studies may thus partly be explained by a presumed better fit of the framework used[31] and because of increased experience and knowledge achieved by the clinicians (learning curve). Another reason for the high fracture rate could be the degree of resorption of the arches treated. The arch shape grading showed that the bicortical group was more resorbed (Table 1), which might have resulted in an unfavorable arch relationship, ie, toward a Class III relation. Such interarch situations may create unfavorable stress and bending forces on the implants, as well as on the bone tissue.[29] Furthermore, severe arch resorption often demands longer abutments to compensate for lost hard and soft tissues, which may also have contributed to an unfavorable lever situation.[7,32] Taking into account these factors in combination with theoretically firmer anchorage of the bicortically anchored implants,[13,33,34] stress levels on the implant components that were too high may have been reached, resulting in the subsequent implant fractures.

The obtained result applicable to the biocortically anchoraged implants was somewhat surprising, as in previous clinical studies it has been recommended that implants should be bicortically stabilized whenever possible.[5–8] Brånemark and coworkers[9] showed, over an observation period of 5 to 10 years, a success rate of 71% for sinus- and nasal-penetrating implants. For a shorter follow-up period (2 to 5 years), a success rate of 92% was revealed, which is close to the result in the current study. Furthermore, a prospective clinical short-term study has indicated better implant success rates for bicortically anchored implants, especially in the maxilla, where the success rate was twice the success rate for monocortically anchored implants.[10] From experimental findings, higher removal torque values and greater bone-to-implant contact have also been reported for unloaded bicortically anchored implants in rabbit tibia.[13] Although it was not possible in this study to demonstrate an improvement in maxillary implant successes over a 15-year period for bicortically anchored implants, such anchorage may be advantageous in the treatment of arches with low bone densities, a statement that also is supported by findings in a FEM study by Van Oosterwyck et al.[14]

Overloading of implants has been reported to cause marginal bone resorption.[35,36] With gradual bone loss, the weaker portion of the implant (at the end of the abutment screw) might with time be exposed and the anchorage unit thereby become more vulnerable to bending forces.[28] However, as the total marginal bone loss was low over the 15-year period and close to identical for the 2 groups, this likely was not the case in this study. The current result of minor marginal bone loss also suggests that the mode of anchorage did not have any clinically significant influence on marginal bone remodeling, even if FEM studies have related established stress concentrations at the crestal bone (Figs 3 and 4) to the amount of cortical bone present.[15,19]

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CONCLUSIONS

In this retrospective study, bicortically anchored implants showed an implant fracture rate that was 3 times higher than monocortically anchored implants, which may be interpreted as resulting from fixation that was too stable for the bicortical type of anchorage. As possible explanations, increased stress and bending forces because of prosthetic misfit, unfavorable arch relationships, and high occlusal tables, in combination with bicortically anchored implants, may be suggested. However, it should be noted that such confounding variables as smoking, opposing occlusion, cantilever length, and parafunction were not evaluated. The loss of patients to follow-up could have impacted the results as well.

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