Implant-Supported Overdentures: A Longitudinal Prospective Study

Tom Bergendal, DDS, Odont Dr*/Bo Engquist, DDS**

The aim of this study was to evaluate the clinical function and long-term prognosis of overdentures retained by a small number of implants in the maxilla and mandible using one of two different attachment systems. Included in the study were all patients referred to specialty clinics in Jönköping and Linköping, Sweden, during the treatment period who needed an overdenture and could be provided with a minimum number of two bilaterally-placed implants. Excluded were patients with bone-grafted jaws, irradiated cancer patients, heavy bruxers, and patients who had lost a fixed prosthesis because of implant losses. The patients were randomly assigned to receive one retentive system, either a round 2-mm-diameter bar with clips or ball attachments (Nobel Biocare). Eighteen overdentures were placed in maxillae and 32 in mandibles, supported by a total of 115 Brånemark implants. Of the implants placed, 86.1% were continuously osseointegrated. The cumulative implant survival rates after 7 years of loading were 75.4% in the maxillae and 100% in the mandibles. There was no difference in implant survival rate between the attachment systems. Patients with implant losses were characterized by severely resorbed maxillary ridges and inferior bone quality, together with unfavorable loading circumstances such as short implants combined with long leverages. Complications and prosthetic adjustments were mostly resolved early and easily.
(INT J ORAL MAXILLOFAC IMPLANTS 1998;13:253–262)

Key words: Brånemark implants, oral implants, overdenture

The placement of multiple Brånemark implants for fixed prostheses has been shown to be a predictable method for long-term treatment of edentulous patients.[1–9] Limitations such as severely resorbed jaws, large antra, unfavorable jaw relations, and financial restrictions sometimes prevent the placement of a sufficient number of implants to accommodate a fixed prosthesis and therefore require an alternative for edentulous patients with compromised oral function. The basic concept of placing a limited number of implants to support an overdenture could be such an option. The success of this therapy has not been documented with long-term follow-up, and earlier studies have indicated a high frequency of implant losses in the maxilla.[10–16]

The objective of the present prospective study was to evaluate the implant survival rate, clinical function, and long-term prognosis of overdentures in the maxilla and mandible using two different attachment systems with a limited number of supporting implants.

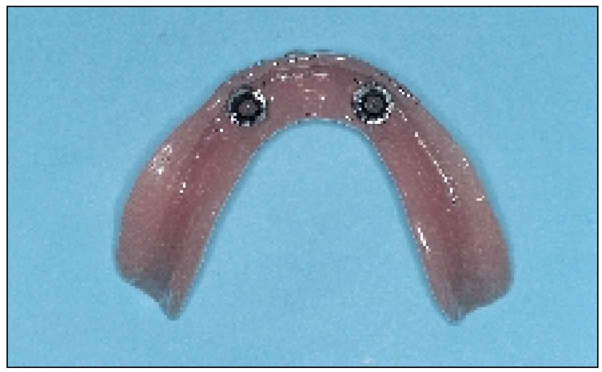
Materials and Methods

Patient selection. The material comprised 49 patients, 16 males and 33 females aged 7 to 82 years (median age 66 years). All patients were referred to the Specialist Clinics of Prosthodontics in Jönköping and Linköping, Sweden, for prosthetic rehabilitation. The basic inclusion criteria were edentulous patients in need of an overdenture and in whom at least one implant could be placed bilaterally. The reasons for choosing overdenture therapy included: financial, 29 (28 in the mandible); morphologic, 15 (all in the maxillae); diverging maxillomandibular relations, 3; and other reasons, 3. Bruxers, bone-grafted individuals and irradiated cancer patients were excluded, as were patients with a history of failed implant-supported fixed prostheses. Patient selection was based on clinical and radiographic examinations. Routine Orthopantom-

*Head, Department of Prosthodontics, Institute for Postgraduate Dental Education, Jönköping, Sweden.
**Head, Specialist Center Oral Rehabilitation, Linköping, Sweden.

Reprint requests: *Dr Bo Engquist, Specialist Center Oral Rehabilitation, S-581 85 Linköping, Sweden. Fax:+46 13 228847*

Figs 1a and 1b *(Left)* Round 2-mm clasp bar *(right)* with clips.



Figs 1c and 1d *(Left)* Ball attachments *(right)* with rubber ring retention.

Table 1 Distribution by Jaw of 115 Activated Implants

	No. of implants supporting each denture				
Jaw/attachment	2	3	4	5	Total
Maxilla					
Bar	4	4	1	1	10
Stud	6	2	—	—	8
Mandible					
Bar	15	3	—	—	18
Stud	13	1	—	—	14
Total	38	10	1	1	50

ograms and lateral radiographs were supplemented with tomographic examinations in the maxillae and in severely atrophied areas in the mandibles. The primary selection of patients was based on an evaluation of the bone morphology according to Lekholm and Zarb.[6]

Selection of Retentive System. One of two retentive systems was chosen for each overdenture: a round 2-mm alveolar clasp bar without extensions and with clips (Cendres Metaux, Biel Bienne, Switzerland; J. Sjöding, Stockholm, Sweden) or ball attachments with rubber ring retention (Nobel Biocare, Göteborg, Sweden) (Figs 1a to 1d). The patients were randomly assigned to bar or ball attachments. In two patients, however, the chosen system could not be used because of an unfavorable distribution or inclination of the implants, and in one patient, the round bar was exchanged for an individually cast bar because of limited vertical space. A total of 28 overdentures were retained by bar/clip attachments and a total of 22 by ball/O-ring attachments. The distribution per jaw of attachment system and activated implants is shown in Table 1.

Clinical Procedures. The patients were treated by specialists in oral surgery at the two institutions according to the protocol by Brånemark and coworkers.[2] The oral surgeons recorded the jaw bone quality and quantity at the time of implant placement based on preoperative radiographs, visual inspections, and tactile perception during surgery. Endosseous Brånemark system implants (Nobel Biocare), with a diameter of 3.75 mm and with lengths ranging from 7 to 20 mm, were used. Generally, specialists in prosthodontics performed the prosthetic treatment. Accepted principles were used for establishing the occlusal plane, freeway, space, and occlusal stability with freedom of centric relation.[17,18]

Examination and Follow-Up Schedule. The study was performed as a prospective investigation, and the patients were consecutively recorded, treated, and followed between January 1984 and December 1994. An examination protocol was established and the clinicians were calibrated before the start of the study. Baseline radiographic and clinical examinations were performed at the time of prosthesis placement and then annually thereafter. A number of variables were registered.

Implant Survival. The following criteria (from Ahlqvist et al)[3] were used to define implant survival: the implant should be in function and clinically stable when tested individually; there should be no pain from the implants; the peri-implant soft tissues should be clinically healthy or show only a mild degree of inflammation; and radiographs should not demonstrate radiolucencies or other pathologic conditions adjacent to the implant. Cumulative implant survival rates in maxillae and mandibles were calculated using Life Table methods.[7,19]

Marginal Bone Loss. Standardized radiographs of the implants were taken using the long-cone technique according to Strid[8] at the baseline examination and then annually thereafter. The mean marginal bone loss was measured on the annual radiographs at the mesial and distal sides of the implants to the closest 0.5 mm. The implant abutment connection line served as the reference point. If the examiners disagreed about the amount of bone loss, a new evaluation was performed until examiner consensus was reached. At sites where two different bone levels could be seen, the most apical level was used in the measurement.

Lever Arm–Bone Anchorage Ratio. A formula ratio

$$\frac{\text{Lever arm (BL + B + A)}}{\text{Bone anchorage F}}$$

was used to calculate the quotient between the lever arm above the bone level and the bone-anchored part of each implant (Fig 2).

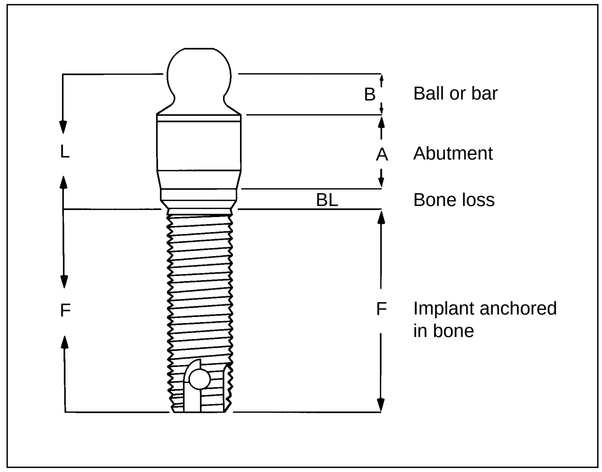


Fig 2 Schematic distances used to calculate the lever arm ratio.

Plaque and Gingivitis. Patients were referred to dental hygienists for maintenance care. Visible plaque or no plaque, as well as bleeding or no bleeding on probing, were registered at four sites around the abutments for evaluation of the hygiene and the condition of the peri-implant soft tissues.

Oral Mucosa. The denture-supporting mucosa was examined for denture-induced stomatitis and visible denture plaque. Any candida growth at the denture base and mucosa was recorded and treated.[20] Patients were instructed in denture hygiene.

Evaluation of the Prostheses. Retention, stability, occlusion, cracks, and fractures of the overdentures, as well as defects in the attachments, were the prosthetic variables recorded. Retention of the overdenture was deemed *acceptable* if an evident active retention could be found when applying force to the denture in the direction opposite to that of placement.

The stability was *acceptable* if only minor movements were observed when rotating and tipping the overdenture.

The occlusion was *acceptable* when a bilateral stable intercuspal position without interferences existed during repeated habitual biting.

All parts of the retentive elements were examined and classified as *acceptable* if they were intact.

If any of the prosthetic variables listed above were classified as *not acceptable,* prosthetic measures were performed to optimize the function of the dentures, and the different technical measures undertaken were recorded.

Subjective Evaluation. The patients' own appreciation of the overdenture therapy was evaluated in a five-point questionnaire: How do you find your overdenture on the whole? How does it stay in place?

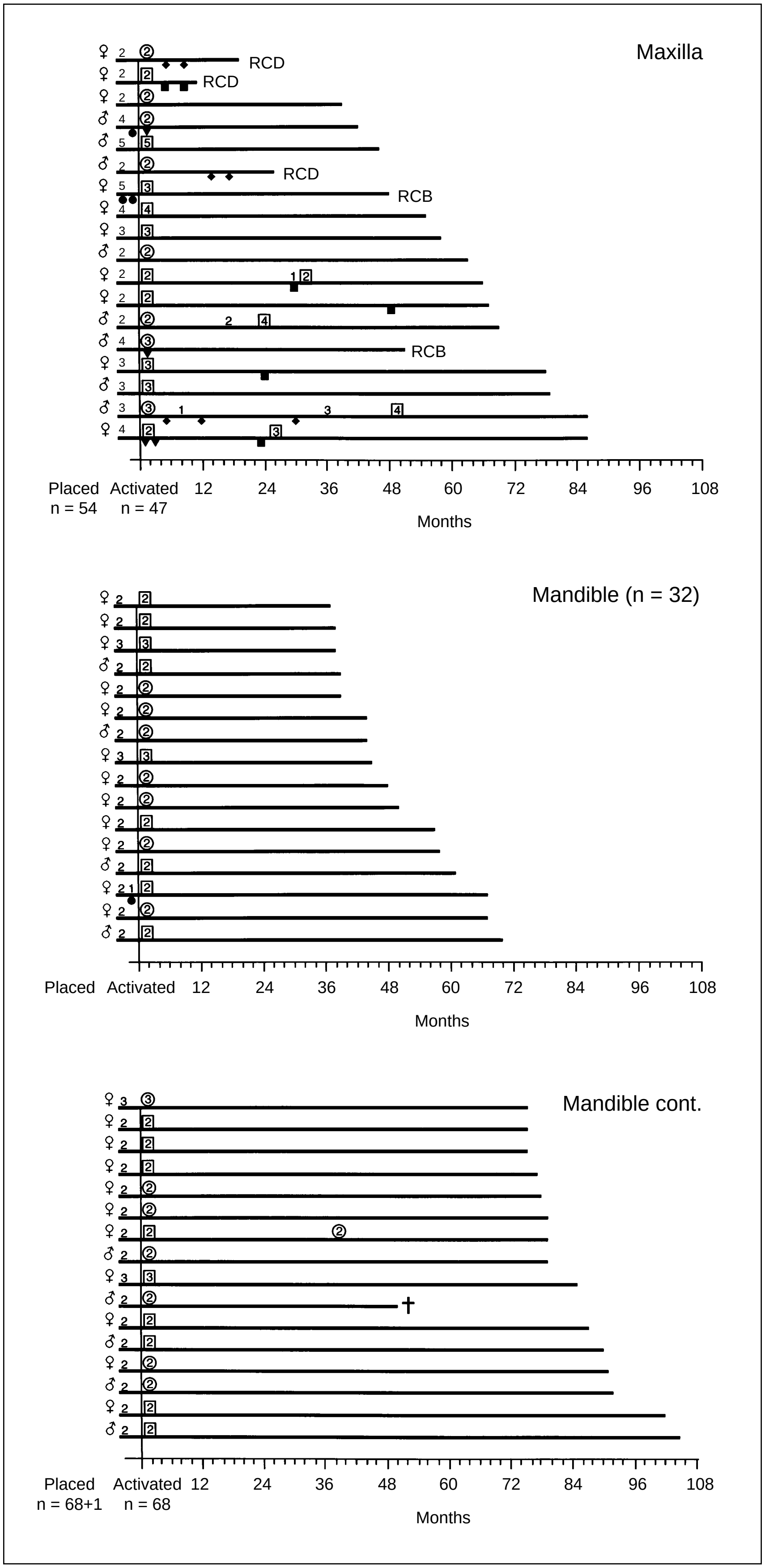


Fig 3 Calendar time scale for each maxillary and mandibular implant placed, loaded, lost, reoperated, sleeping, or reactivated. RCD = number referred to complete denture; RCB = number referred to complete bridge.

2 Placed
[2] Activated bar
(2) Activated ball

▼ Sleeping
■ Lost, bar
◆ Lost, ball
● Lost before activated
✝ Deceased

Table 2 Total Number and Percentage of Implants Placed and Lost Before and After Loading With Overdentures

Jaw	No. of implants Placed	Loaded	No. of implants lost Before loading	After loading	Total
Maxilla	54*	47	3 (5.6)	13 (27.7)	16 (29.6)
Mandible	68	68	1 (1.5)		1 (1.5)
Total	122	115	4	13	17 (13.9)

*Includes four sleeping implants.

Table 3 Life Table Analysis of Maxillary Implant Survival Rate

Interval (yrs)	Implants loaded at start of interval (n)	Implants scheduled for withdrawal in the interval (n)	Implants observed for full interval (n)	Implants failing in interval (n)	Interval failure rate (%)	Interval survival rate (%)	Cumulative survival rate (%)
0–1	47 + 9*	0	56	6	10.7	89.3	89.3
1–2	50	0	50	5	10.0	90.0	80.4
2–3	45	0	45	1	2.2	97.8	78.6
3–4	44	10	34	0	0	100	78.6
4–5	34	18	16	1	4.0	96.0	75.4
5–6	15	8	7	0	0	100	75.4
6–7	7	5	2	0	0	100	75.4
7–8	2	2	0	0	0	100	

*Seven implants reoperated and two sleeping implants activated.

How does it function when chewing? How does it function when talking? How does it look? The possible answers were *good, rather good, rather bad,* and *bad.*

Results

In the present study, 49 patients with 50 overdentures, 18 in maxillae and 32 in mandibles, were followed for a period of up to 10 years (Fig 3). Six patients dropped out: one died, two returned to complete dentures because of implant losses, and two had additional implants placed and were fitted with fixed prostheses. One patient, who underwent a second surgical procedure and bone graft, was excluded. The final total of 43 patients constituted a cohesive group during the study period. The mean observation time was 62 months. The total number of implants placed and lost, both before and after loading, is presented in Table 2. Individual implant distribution and survival are described in Fig 3, which present the numbers of placed, loaded, lost, reoperated, sleeping, and reactivated implants in the maxillae and mandibles.

No loaded implants were lost in mandibles. The maxillary results were transferred to a Life Table (Table 3). The cumulative implant survival rate for maxillae was 75%. Eight patients lost 13 (28%) maxillary implants after loading. Four patients account for 69% (9/13) of the implant losses in maxillae. Nearly half (46%) (6/13) of the implant losses occurred during the first 12 months. The median time in function for the other 7 implants that failed was 26 months, with a range of 14 to 48 months. Four patients lost all of their implants. Two of them returned to complete dentures. Three patients had new implants placed, and one of them underwent a bone graft. One patient had 2 sleeping implants activated. Two other patients were treated with fixed prostheses after supplementary implant placement (Table 4).

The morphologic characterization of the jawbone in relation to the total number of placed and lost implants is shown in Table 5. Eighty-five percent (11/13) of the lost maxillary implants were placed in jawbone of inferior quality and quantity. Seventy-nine percent (11/14) of all maxillary implants were placed in bone of quality type D, and 58% (11/19) of implants placed in quantity 4 or 5 were lost.

The anatomic prerequisites for the placement of oral implants led to the use of implants of different lengths in different bone sites. Short implants (7 mm and 10 mm) were less frequent (25%) in the mandibles than longer implants (13 to 20 mm), while in the maxillae, 49% of implants were of shorter lengths (7 mm and 10 mm). The lengths of the 115 activated implants and connected abutments are pre-

Table 4 Characteristics of the Eight Patients With Implant Losses in the Maxilla After Loading

Sex/age at placement	Implant length (mm)	Attachments	Ratio L/F*	Bone quality	Bone quantity	Angle class	Opposite jaw	In function (mo)	Reoperated implant (n)	Present status
Male/59	7	Ball	1.2	D	4	III	OIP	3	4	4-implant OD
	7		1.6					8		
	7		2.1					30		
Female/66	18	Bar	0.8	D	4	I	Bridge	22		2-implant OD
Female/65	13	Bar	0.9	C	3	I	OIP	29	1	2-implant OD
Female/72	10	Ball	2.2	D	4	III	RPD	14		CD
	10		1.5					19		
Female/63	10	Bar	1.1	D	4	I	RPD	9		CD
	13		1.0					11		
Female/68	13	Bar	1.1	C	3	III	Dentate	22	2 sleeping implants activated	3-implant OD
Female/62	10	Bar	1.0	D	4	I	Dentate	48		1-implant OD
Male/47	15	Ball	1.0	D	4	I	Dentate	12	2 implants bone-grafted	2-implant OD
	15		1.0							

OIP = osseointegrated prosthesis; RPD = removable partial denture; OD = overdenture; CD = complete denture.
*See Fig 2.

Table 5 Morphologic Characterization of Jawbone in Relation to the Total Number of Implants Placed (and Lost) After Loading

	No. of implants placed (and lost)								
	Bone quality*				Bone quantity*				
Jaw/attachment	A	B	C	D	1	2	3	4	5
Maxilla									
Bar		13	9 (2)	7 (4)			22 (2)	7 (4)	
Ball		2	9	7 (7)			6	12 (7)	
Mandible									
Bar	4	9	26		2	12	18	5	2
Ball		14	11	4	2	4	23		

*According to Lekholm and Zarb.[6] Shaded columns denote bone of inferior quality/quantity.

Table 6 Length of Activated Implants and Abutments (n = 115)

	Implant length (mm)*						Abutment length (mm)*				
Jaw/attachment	7	10	13	15	18	20	3	4	5.5	7	8.5
Maxilla											
Bar	3	14 (2)	10 (3)	1	1 (1)		3	6 (1)	16 (5)	4	
Stud	3 (3)	3 (2)	3	9 (2)			1	10	3 (5)	4 (2)	
Mandible											
Bar	3	11	11	12		2	1	11	17	7	3
Stud		3	13	9	4		2	11	14	2	
Total	9 (3)	31 (4)	37 (3)	31 (2)	5 (1)	2	7	38 (1)	50 (10)	17 (2)	3

*Numbers of implants lost are in parentheses.

sented in Table 6, which shows that 50% (3/6) of the 7-mm-long maxillary implants were lost. Thirty percent (7/23) of the short implants (7 mm and 10 mm) and 25% (6/24) of the longer implants (13 to 18 mm) were lost. Table 6 also shows that 92% (12/13) of the lost implants were fitted with abutments ≥ 5.5 mm, and the remaining 8% (1/13) with a shorter abutment.

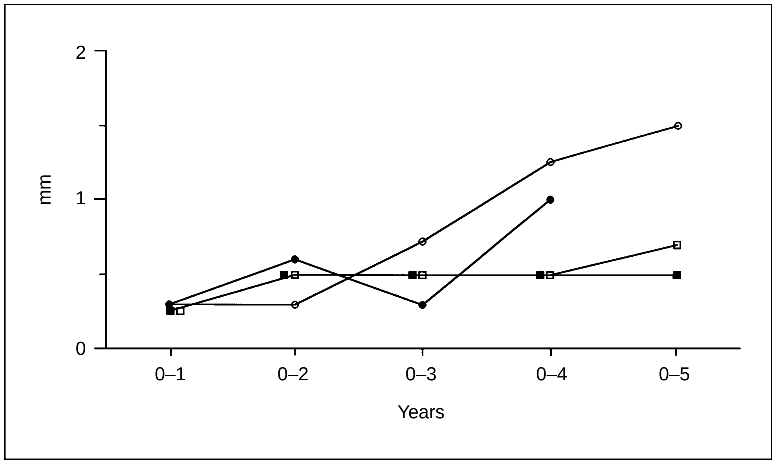
The anatomic prerequisites also resulted in longer lever arms and higher lever arm ratios in the maxillae than in the mandibles, 1.0 versus 0.9, respectively (Table 7 and Fig 2). The mean lever arms were thus 1.0 times longer than the mean bone-anchored part of the implant in the maxillae, and 0.9 times as long as the implants in the

Table 7 Lever Arm–Bone Anchorage Ratio*

Jaw/attachment	Ratio (day 0)** 0.50–1.00	1.01–2.30	Mean value
Maxilla			
Bar	13 + (4)	10 + (2)	1.12 (0.98)
Ball	8 + (2)	1 + (5)*†	0.83 (1.60)
Total	21 + (6)	11 + (7)	1.04 (1.31)
Mandible			
Bar	22	17	1.03
Ball	27	2	0.74
Total	49	19	0.91

*See Fig 2.
**Numbers of implants lost after loading are in parentheses.
†One patient with two implants was excluded because of inadequate radiographs.

Fig 4 Median marginal bone loss in the maxillae (bar ○, ball ●) and in the mandibles (bar □, ball ■).



mandibles. The mean lever arm values for lost implants was 1.3. This negative loading condition was most evident for implants connected to ball attachments in the maxillae, where the lever arm ratio was 1.6. The figures relate to day 0 and increased with progressive marginal bone loss.

Concluding characteristics of the eight patients with implant losses are shown in Table 4. The most common failure situation could be described as a maxillary overdenture with either a bar (5/8) or ball (3/8) attachment and short implants (7/13), a higher lever arm ratio (1.3), and inferior bone quality (6/8). The mean time in function was 18 months and varied from 3 to 48 months.

Median values for marginal bone loss were calculated by measuring at two sites on each implant. The resorption in the mandibles over 5 years was 0.5 to 0.7 mm for the two systems. In the maxillae, final resorption was somewhat higher for both attachment systems and showed great variation between patients (Fig 4). The type and number of technical procedures during the follow-up period are presented in Table 8. Certain measures were recorded at frequent and regular intervals during the years, eg, exchange or activation of the retentive clip or O-ring, rebase or relining of the overdentures, and adjustment of the denture base. Denture repair was overrepresented in bar patients (30/36). No fractured gold or abutment screws were registered, and screw loosening was not a frequent problem.

Table 8 Types of Technical Procedures Carried Out According to the Type of Denture Attachment

Technical procedure	Bar	Ball
Occlusal adjustment	12	11
Rebase/reline	25	24
Adjustment denture base	33	31
Denture repair	30	6
New denture	4	1
Exchange/adjust bar/stud	9	14
Exchange/activate clip/O-ring	64	73
Other	14	26

Patients' own evaluations of the overdenture therapy over 5 years revealed that appreciation of the overdentures did not decrease over the years. The majority of the patients answered the questions with *good* or *rather good.* The answers showed no difference between implant-supported overdentures in the maxilla or in the mandible or between the two attachment systems used.

Discussion

Numerous studies of implant-retained overdentures in mandibles with good results but short follow-up periods have been reported. From these studies, it may be concluded that implant-retained overdentures in mandibles are an established treatment modality with survival rates equal to the results reported from studies with fixed implant-supported prostheses. In the present longitudinal study, the cumulative implant survival rate in mandibles was 100%, which supports the presumption that this treatment also has a good prognosis in a long-term perspective. Jaw bone quality proved to be important for the continuous osseointegration of implants supporting overdentures. In this study, the relationship between the loading conditions and osseointegration in the mandibles has proven to be favorable for the two retentive systems, round bar with clips or ball attachments. The compact bone in the symphysis region between the mental foramina seems to be sufficient to ensure excellent results over long periods.

This study also highlights the contrast between treatment results for overdentures in the maxilla versus the mandible. The cumulative implant survival rate for maxillae was 75% after 6 years, with the last implant loss occurring 4 years after loading. The losses were similar between the two retentive systems. These results concur with those of Hutton et al,[13] who reported survival rates of 74% after 3 years in a multicenter study. In that study, however, 9 of 29 lost implants were removed before loading with overdentures, and all of the loaded implants were connected to bars. The interaction between bone quality and quantity was the most predictable factor for implant loss.

In a retrospective multicenter study,[11] patients were divided into two groups according to bone morphology. Most implant losses occurred in the group with inferior bone quality and prior to loading of the implants. This pattern can also be observed in other studies.[10,14,16,21]

Early implant losses (before loading) indicate selection difficulties and problems in recognizing and identifying at-risk patients with inferior bone morphology before the start of treatment.[6,11,14,16,22,23] If the implants placed are too short and occupy a small osseointegration area, they might be unable to withstand the stresses from dentures during function. Enlarging the area of osseointegration by using longer or wider implants or by placing a greater number of supporting implants are possible alternatives,[15,16,21,24] as are bone-grafting methods. However, there are also indications that four or more implants connected to fixed prostheses have an excellent prognosis.[5]

The morphologic characterization of the jaw bone (Table 5) and the lengths of implants and abutments (Table 6) illustrate the condition of the jaw bone and selection of implant lengths made by the oral surgeons. Despite a thorough clinical examination and the use of radiologic aids, eg, computed tomography, a total of 28% of the implants were placed in bone of soft quality type D in the maxillae. Eighty-five percent of the implants placed in that bone quality failed. The figures for the eight patients with implants lost after loading (Table 4) reveal that six had implants placed in bone of type D. The combination of soft bone and short (7 mm and 10 mm) implants (7/13) with long leverages (11/13) resulted in implant failures as a consequence of overloading a small osseointegration area. This is the most evident difference between early implant losses related to insufficient or nonexistent osseointegration and losses that occurred after several months. Late losses must be interpreted as the result of overloading of achieved osseointegration in bone of inferior quality, if not an infection.

Marginal bone loss was measured up to 5 years and related to attachment system and jaw. The results were in accordance with results from fixed implant-supported prostheses.[13,25–28] There were wide individual variations in the patient group, but both jaws had low median values that were somewhat higher in the maxillae (Fig 4).

In a longitudinal study of removable partial prostheses over 10 years,[29] one of the conclusions was that a large number of technical procedures had to be undertaken to maintain optimal function of the dentures. The same pattern is recognized in this and other studies with implant-supported overdentures.[16,30–32] When scrutinizing the number of technical procedures needed to maintain good function in the present study (Table 8), it was found that most of the technical problems occurred early in the treatment period. The reason for this was that in the mid-1980s when the study was initiated, the retentive systems were not fully developed. Thus, such problems as unscrewed ball attachments, worn O-rings, damaged female housings, or fractured retentive clips were encountered. During later years, the situation improved and hence the frequency of technical problems decreased. Furthermore, the relatively high rate of denture repair in bar-supported dentures may be explained by the lack of reinforcement of cobalt chromium frameworks, which might be recommended.

In this study, patients were randomly assigned to one of two retentive systems. The results were as good for noninterconnected as for bar-interconnected implants.[31] However, there are no unambiguous results indicating which attachment system is to be preferred in specific situations. Thus, in patients with implant losses, there was an equal distribution of bar and ball systems, but in the individual cases of failure, the ideal loading situation was evidently not found. For example, a short straight bar can certainly cause low stress to the implants and can also impair denture stability.[13,15,24,25] However, if the distance between the abutments is long, the bar will be long, curved, and weak. The elasticity will then increase and cause a different and more complex stress distribution, perhaps worse than on separate ball attachments.

Shortening the lever arm by using short abutments, preferably on long implants, favors stress distribution from bars, as well as from separate attachments. A lever arm–bone anchorage ratio was calculated to evaluate the relation between osseointegrated implant length and lever arm length. This traumatic factor was recognized, since the mean ratio for lost implants in the maxillae was higher (1.3) especially for short implants with ball attachments (1.6). In the maxillae, the denture-bearing oral mucosa is often thick, necessitating the use of long abutment cylinders to penetrate the soft tissue. If the implants are placed into a thin, sharp alveolar ridge that undergoes marginal resorption during the first years, the lever arm increases and a gradual overload can occur. A reduction of the mucosal thickness around the abutments could improve the lever arm ratio and improve the clinical prerequisites for optimal loading design of the superstructures.

Conclusions

In this long-term follow-up of overdentures in both jaws, supported by a limited number of implants, and retained by one of two different attachment systems, it was found that:

1. The long-term prognosis in the mandible was excellent.
2. The implant survival rate in the maxilla was lower than in the mandible because of bone morphology and loading conditions.
3. To reduce stress distribution to the implants, the lever arm should be kept as short as possible by using short abutments.
4. There was no difference in implant survival between the two randomly distributed attachment systems. However, optimization of the loading conditions on an individual basis with different attachments may contribute to a higher survival rate.
5. One cannot apply long-term results obtained in the mandible directly to the maxilla, which differs in bone morphology and loading circumstances. Careful evaluation of the bone morphology and loading in each individual case must be undertaken before treatment. Guidelines for this planning are needed.

References

1. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347–359.
2. Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985.
3. Ahlqvist J, Borg K, Gunne J, Nilsson H, Olsson M, Åstrand P. Osseointegrated implants in edentulous jaws: A 2-year longitudinal study. Int J Oral Maxillofac Implants 1990;5:155–163.
4. Jemt T. Implant treatment in resorbed edentulous upper jaws. A three-year follow-up study on 70 patients. Clin Oral Implants Res 1993;4:187–194.
5. Brånemark P-I, Svensson B, van Steenberghe D. Ten-year survival rates of fixed prostheses on four or six implants ad modum Brånemark in full edentulism. Clin Oral Implants Res 1995;6:227–231.
6. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
7. Shulmann LB, Rogoff GS, Savitt ED, Kent RL. Evaluation in reconstructive implantology. Dent Clin North Am 1986;30:327–349.
8. Strid KG. Radiographic procedures. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:317–327.
9. Quirynen M, Naert I, van Steenberghe D, Schepers E, Calberson L, Theuniers G, et al. The cumulative failure rate of the Brånemark system in the overdenture, the fixed partial, and the fixed full prostheses design: A prospective study of 1273 fixtures. J Head Neck Pathol 1991;10:43–53.
10. Naert I, Quirynen M, Theuniers G, van Steenberghe D. Prosthetic aspects of osseointegrated fixtures supporting overdentures. A 4-year report. J Prosthet Dent 1991;65:671–680.
11. Engquist B, Bergendal T, Kallus T, Lindén U. A retrospective multicenter evaluation of osseointegrated implants supporting overdentures. Int J Oral Maxillofac Implants 1988;3:129–134.
12. Palmqvist S, Sondell K, Swartz B, Svensson B. Marginal bone levels around maxillary implants supporting overdentures or fixed prostheses: A comparative study using detailed narrow-beam radiographs. Int J Oral Maxillofac Implants 1996;11:223–227.

13. Hutton JE, Heath R, Chai JY, Harnett J, Jemt T, Johns RB, et al. Factors related to success and failure rates at 3-year follow-up in a multicenter study of overdentures supported by Brånemark implants. Int J Oral Maxillofac Implants 1995;10:33–42.
14. Palmqvist S, Sondell K, Swartz B. Implant-supported maxillary overdentures: Outcome in planned and emergency cases. Int J Oral Maxillofac Implants 1994;9:184–190.
15. Smedberg J-I, Lothigius E, Bodin I, Frykholm A, Nilner K. A clinical and radiological two-year follow-up study of maxillary overdentures on osseointegrated implants. Clin Oral Implants Res 1993;4:39–46.
16. Jemt T. Failures and complications in 92 consecutively inserted overdentures supported by Brånemark implants in severely resorbed edentulous maxillae: A study from prosthetic treatment to first annual check-up. Int J Oral Maxillofac Implants 1992;7:162–167.
17. Helkimo M. Various centric positions and methods of recording them. In: Zarb GA, Bergman B, Clayton JA, MacKay HF (eds). Prosthodontic Treatment for Partially Edentulous Patients. St. Louis: Mosby, 1978: Chapter 16.
18. Zarb GA, Fenton AH. Prosthodontic, operative and orthodontic therapy. In: Mohl NO, Zarb GA, Carlsson GE, Rugh JO (eds). A Textbook of Occlusion. Chicago: Quintessence, 1988: 305–328.
19. Colton T. Statistics in Medicine. Boston: Little, Brown, 1974: Chapter 9.
20. Bergendal T. Treatment of denture stomatitis [thesis]. Stockholm, Karolinska Institute, 1982.
21. Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Brånemark system. Clin Oral Implants Res 1992;3:104–111.
22. Cune MS, de Putter C, Hoogstraten J. Treatment outcome with implant-retained overdentures: Part I. Clinical findings and predictability of clinical treatment outcome. J Prosthet Dent 1994;72:144–151.
23. Cune MS, de Putter C, Hoogstraten J. Treatment outcome with implant-retained overdentures: Part II. Patient satisfaction and predictability of subjective treatment outcome. J Prosthet Dent 1994;72:152–158.
24. Engquist B. Overdentures. In: Worthington P, Brånemark P-I (eds). Advanced Osseointegration Surgery: Application in the Maxillofacial Region. Chicago: Quintessence 1992:233–247.
25. Naert I, Quirynen M, Hooghe M, van Steenberghe D. A comparative prospective study of splinted and unsplinted Brånemark implants in mandibular overdenture therapy: A preliminary report. J Prosthet Dent 1994;71:486–492.
26. Gotfredsen K, Holm B, Sewerin I, Harder F, Hjörting-Hansen E, Pedersen CS, et al. Marginal tissue response adjacent to Astra dental implants supporting overdentures in the mandible. A 2-year follow-up study. Clin Oral Implants Res 1993;4:83–89.
27. Donatsky O. Osseintegrated dental implants with ball attachments supporting overdentures in patients with mandibular alveolar ridge atrophy. Int J Oral Maxillofac Implants 1993;8:162–166.
28. Johns R, Jemt T, Heath MR, Hutton JE, McKenna S, McNamara DC, et al. A multicenter study of overdentures supported by Brånemark implants. Int J Oral Maxillofac Implants 1992;7:513–522.
29. Bergman B, Hugoson A, Olsson C-O. Caries, periodontal and prosthetic findings in patients with removable partial dentures: A ten-year longitudinal study. J Prosthet Dent 1982;48:506–514.
30. Hemmings KW, Schmidt A, Zarb GA. Complications and maintenance requirements for fixed prostheses and overdentures in the edentulous mandible: A 5-year report. Int J Oral Maxillofac Implants 1994;9:191–196.
31. Mericske-Stern R, Steinlin Schaffner T, Marti P, Geering AH. Peri-implants mucosal aspects of ITI implants supporting overdentures. A five-year longitudinal study. Clin Oral Implants Res 1994;5:9–18.
32. Mericske-Stern R. Clinical evaluation of overdenture restorations supported by osseointegrated titanium implants. A retrospective study. Int J Oral Maxillofac Implants 1990;5:375–383.