Maxillary Overdentures Retained by Splinted and Unsplinted Implants: A Retrospective Study

Timo O. Närhi, DDS, PhD[1]/Miluska Hevinga, DDS[2]/
Ralph A. C. A. Voorsmit, DDS, PhD[3]/Warner Kalk, DDS, PhD[4]

The purpose of this retrospective study was to evaluate the clinical performance of and patients' satisfaction with maxillary overdentures retained by splinted and unsplinted implants. Patients who had been treated with maxillary implant-retained overdentures because of functional problems with conventional complete dentures were identified and invited to participate in the study. A total of 16 patients fulfilled the enrollment criteria and agreed to participate. Eleven patients were treated with bar-retained overdentures with 3 to 6 clips (mean follow-up 32 months), and 5 patients wore overdentures retained by 2 to 6 ball attachments (mean follow-up 54 months). All subjects were satisfied with their prostheses, and most subjects experienced improvement in their oral function after treatment with implant-retained overdentures. At the time of clinical examination, 92% (n = 77) of the 84 implants placed were functioning satisfactorily. The cumulative survival rate for the implants after 72 months was 90%. Loss of bone support correlated with peri-implant probing depth (r = 0.29; P < .02). No differences in mean bone loss between the subjects with ball-retained or bar-retained overdentures were found. The presence of plaque or peri-implant bleeding was not associated with the type of attachment. (Int J Oral Maxillofac Implants 2001;16:259–266)

Key words: *alveolar bone loss, dental implants, overdentures, patient satisfaction, peri-implant health*

Many of the problems reported by conventional complete denture wearers can be eliminated when implants are used to support fixed prostheses or removable overdentures. A number of reported longitudinal studies confirm the effectiveness of this treatment in the mandible,[1,2] even in patients with severe alveolar bone loss,[3] but results in the maxilla have been mixed.[4,5] Atrophy of the edentulous maxilla limits the opportunities for implant placement, and because of fine and delicate trabecular bone with a thin or even absent cortical plate, it is considered unpredictable for stabilizing and supporting dental implants.[6] Close proximity of the maxillary sinus and nasal floor may further complicate maxillary implant treatment, and extensive reconstructive procedures are often needed before implant placement.[7] Occasionally, it may be possible to place 2 to 4 implants without surgical reconstruction, a treatment that has been offered to selected patients. Because of early implant failures, some patients have been treated with fewer implants than originally intended, but clinical outcomes of these treatments have been reported only sparsely.[8]

Implant treatment is often evaluated using the implant survival rate as an indicator for a successful treatment result. All implants that are functioning and do not need immediate removal are usually included in the calculation of survival rates.[2,4,9,10] However, there has been increasing concern that failing implants, ie, implants that will be lost in the near future, should also be considered in implant survival analysis.[11,12] Increased implant mobility and extensive peri-implant bone loss are generally accepted criteria for designating an implant as failing.[13] The importance of the marginal gingival condition for implant survival is still a controversial issue.[12,14]

[1]Assistant Professor, Department of Prosthetic Dentistry, Institute of Dentistry, University of Turku, Finland.
[2]Oral Function and Prosthetic Dentistry, University of Nijmegen, Dental School, Nijmegen, The Netherlands.
[3]Associate Professor, Department of Oral and Maxillofacial Surgery, University Hospital Nijmegen, The Netherlands.
[4]Professor, Oral Function and Prosthodontics, University of Groningen, The Netherlands.

Reprint requests: Dr Timo Närhi, Department of Prosthetic Dentistry, Institute of Dentistry, University of Turku, Lemminkäisenkatu 2, 20520 Turku, Finland. Fax: +358 2 3338356. E-mail: timo.narhi@utu.fi

Portions of this paper were presented at the annual meeting of the International Association for Dental Research, March 12, 1999, Vancouver, Canada.

The aim of the present retrospective study was to determine peri-implant health and loss of bone support around splinted and unsplinted implants used to retain maxillary overdentures. Function of the overdentures, as well as patients' experiences with their prostheses, was also evaluated.

MATERIALS AND METHODS

All patients who had been treated with implant-retained maxillary overdentures at the University of Nijmegen between 1992 and 1996 were identified. Implant patients attended recall examinations annually, but to obtain extensive information concerning their oral status, patients who had received implant-retained maxillary overdentures at least 1 year prior to the onset of the study were invited to undergo a comprehensive oral health examination. Oncologic and congenital cleft palate patients were excluded from the study. A total of 20 patients fulfilled the inclusion criteria, and 16 agreed to participate. One of the excluded participants had lost all implants, 1 subject was too ill, and 2 declined to participate.

Subjects' oral status was evaluated from previously designed history forms, and their subjective opinion about the implant treatment was studied by questionnaire. All participants were examined by 3 experienced clinicians—2 prosthodontists and 1 oral surgeon. Panoramic radiographs, intraoral periapical radiographs of individual implants, and lateral cephalographs were obtained during the study. Information regarding surgical treatment and postoperative complications was obtained from patients' charts.

Clinical Examination

The clinical examination consisted of the following items:

- Occlusion and articulation. The occlusion was considered acceptable if maximal intercuspation coincided with centric relation. Articulation was acceptable if it was balanced during lateral and protrusive movements. The presence of anterior contact in maximal occlusion was also recorded.
- Dentition in the mandible. The type of dentition in the mandible was designated as natural dentition, shortened dental arch with no removable prostheses (RPD), shortened dental arch with RPD, overdenture supported by natural abutments, implant-supported overdenture (4 or more implants), implant/mucosa–supported overdenture (2 implants), or edentulous arch with a complete denture.
- Maxillary overdenture. The type and number of attachments (ball or bar) and presence or absence of palatal coverage were recorded. Prosthesis hygiene was examined by evaluating the presence of staining and soft or hard debris. The number of contacts between clips and bar was evaluated with an occlusal spray (Occlu Spray, Hager & Werken, Duisburg, Germany). Direct contact between the superstructure and denture acrylic resin was also noted.
- Oral mucosa. Occurrence of the following mucosal changes was recorded: *(1)* inflammatory reaction, *(2)* stomatitis, *(3)* ulcers, *(4)* hyperplasia beneath bars, *(5)* labial hyperplasia, *(6)* flabby ridge, and *(7)* angular cheilitis.
- Implant evaluation. The superstructure was removed for implant evaluation. Presence of broken screws, loose abutments, broken abutments, pain around the implants, implant mobility, and pain under horizontal and vertical pressure was recorded. Percussion sound (dull or ping) was examined by tapping the implant vertically. Passive fit of the superstructure was evaluated visually.
- Marginal gingiva around the implants. Peri-implant tissue was evaluated by the following indices:
  1. Plaque Index (according to Silness and Löe[15]) was classified as no plaque, thin plaque film, visible plaque, or abundant plaque on the implant surface.
  2. Peri-implant probing depth (using a Merritt-B pocket probe [Hu-Friedy, Chicago, IL]) was measured in millimeters.
  3. Sulcus bleeding index (according to Mombelli and coworkers[16]) was classified as healthy appearance with or without bleeding on probing and with or without change in color and swelling.

The presence of calculus and purulent exudate from the implant sulcus was recorded, and the width of attached gingiva on the buccal surface, as well as the clinical length of the abutment, were measured using the Merritt-B probe. Based on the clinical evaluation, examiners determined whether or not the subject needed prosthetic or surgical treatment, or whether oral hygiene instructions were required.

Interview

Following the clinical examination, the patients completed questionnaires containing the following categories:

- Dental history. The questionnaire consisted of several items about the conditions before treatment (eg, duration of edentulism, number of

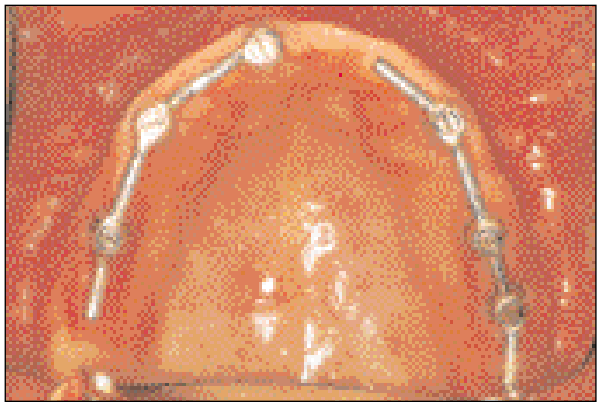

Fig 1 Bar superstructure for maxillary overdenture.

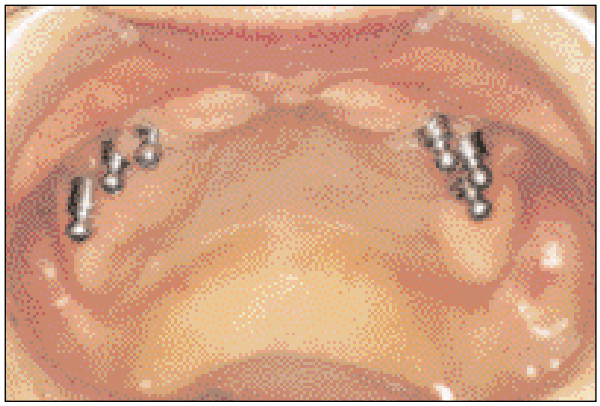

Fig 2 Ball attachments for maxillary overdenture.

complete dentures before implant treatment, main reason for the treatment).

- Problems with previous dentures. This questionnaire consisted of 21 items (yes/no) covering functional problems, eating difficulties, and esthetic complaints.
- Problems with implant-retained overdentures. This category consisted of 53 items to be answered on a 4-point rating scale (0 = no problems, 1 = few, 2 = moderate, 3 = severe). The following areas were covered: functional problems with the maxillary overdenture, functional problems with dentures in general, esthetic complaints, physiognomy, and phonetics.
- Chewing ability. To evaluate the subjective opinion about chewing function, the subjects were asked whether they had no (1), minor (2), or major (3) problems eating different kinds of food items (bread with and without crust, cheese, meat, yogurt, carrots, and apples).
- Overall opinion about maxillary implant-retained overdenture treatment. Participants were asked whether they had problems after implant placement, whether their social contacts had noticed any changes, and whether or not their eating habits had changed because of the implant treatment. The patients were also asked about their expectations for the treatment and whether it had affected their social lives. Patients' oral hygiene habits, as well as their opinion about difficulties with cleaning the intraoral restorations, were also noted. Finally, the patients gave a score ranging from 1 to 10 for their satisfaction with the prosthetic treatment in general.

Statistical Analysis

Statistical analysis was performed using the StatView 4.51 program (SAS Institute, Cary, NC). Comparison of mean bone loss between the subjects with bar-retained (Fig 1) and ball-retained (Fig 2) overdentures was made using the Mann-Whitney *U* test. Associations between various clinical variables were demonstrated with their correlation coefficients. Comparisons of mean scores of the subjective opinion of the treatment (subjects with ball-retained vs. bar-retained overdentures) were made with Student's *t* test.

RESULTS

A bar superstructure with 3 to 6 clips was used to retain the overdentures in 11 subjects, whereas the other 5 subjects had overdentures retained by 2 to 6 ball attachments. Most subjects were edentulous, wearing implant- or implant/mucosa–supported mandibular overdentures. Characteristics of the study population are presented in Table 1.

Lingualized occlusion was used for 13 of the 16 subjects. Of the 3 subjects who did not have lingualized occlusion, 1 had natural dentition in the mandible, and the other 2 had natural dentition supplemented with an RPD. Subjects with natural teeth had canine-guided articulation. Occlusion and articulation were considered adequate in all subjects. The system used to retain the overdentures was effective in all patients.

Mucosal changes were common in the subjects with bar-retained overdentures. Hyperplasia under the bar was seen in 9 subjects (82% of those with bar superstructures), and inflammatory reactions were seen in 8 subjects (50% of all participants). Other mucosal changes were relatively rare (Fig 3).

Of the 48 retentive clips, 11 (23%) had no contact with the bar in maximal occlusion, while 6 implants had direct contact with the denture acrylic resin.

Table 1 Characteristics of Study Population

Patient	Gender	Age (y)	Follow-up (mo)	Implants			Bone grafting?	Type of attachment	Palatal coverage?	Mandibular dentition
				System*	No. placed	No. lost				
1	M	45	22	Brånemark	6	0	Yes	Bar	Yes	Removable partial denture
2	F	65	12	Brånemark	6	0	Yes	Bar	No	Natural
3	M	54	47	Brånemark	2	0	No	Ball	Yes	Implant/mucosa–supported overdenture
4	F	50	57	Brånemark	4	1	Yes	Ball	Yes	Removable partial denture
5	F	55	35	Brånemark	6	4	Yes	Ball	Yes	Overdenture on natural abutments
6	F	55	16	Brånemark	6	0	Yes	Bar	Yes	Implant-supported overdenture
7	F	71	53	Brånemark	6	0	No	Bar	No	Complete denture
8	M	67	9	Brånemark	6	0	No	Bar	No	Implant-supported overdenture
9	F	39	17	Brånemark	6	0	Yes	Bar	Yes	Implant-supported overdenture
10	F	63	33	IMZ	6	0	Yes	Ball	Yes	Implant-supported overdenture
11	M	69	20	Brånemark/ Dyna	6	0	No	Bar	No	Implant-supported overdenture
12	M	66	10	Brånemark	6	1	No	Bar	No	Complete denture
13	F	58	12	Brånemark	4	0	Yes	Bar	Yes	Implant-supported overdenture
14	M	54	47	IMZ	6	0	No	Bar	No	Implant-supported overdenture
15	M	55	20	Brånemark	7	0	Yes	Bar	No	Implant-supported overdenture
16	F	76	14	Brånemark	5	2	No	Ball	Yes	Implant-supported overdenture

*Brånemark implants manufactured by Nobel Biocare, Göteborg, Sweden; IMZ implants manufactured by Interpore International, Irvine, CA; Dyna implants manufactured by Dyna Engineering, Bergen op Zoom, The Netherlands.

Upon removal of the superstructure, 12 loose abutments were detected (19% of all abutments), but none of the screws retaining the superstructures were broken or loose. All superstructures had a passive fit. None of the ball attachments were loose or broken. Vertical and horizontal tapping of the implants caused no pain for any of the implants. However, 1 loose implant was found. The cumulative survival rate for the implants after 72 months was 90% (Table 2). Most implants provided with ball attachments were placed in the canine or premolar regions. Different types of bar superstructures were fabricated utilizing anteriorly or posteriorly placed implants (Table 3).

Information on peri-implant health appears in Table 4. Because of poor-quality panoramic radiographs, bone loss was not determined for 3 participants. Loss of bone support correlated with peri-implant probing depth ($r = 0.29$; $P < .02$). Loss of bone support and peri-implant probing depth seemed to be greater in subjects with ball attachments. However, the differences were not statistically significant. The presence of plaque or peri-implant bleeding was not associated with the type of attachment.

Seven subjects required prosthetic adjustments, and 3 subjects needed further surgical treatment. Five subjects needed additional oral hygiene instructions.

Most subjects were satisfied with their overdentures. Complaint scores were very low, with mean values being just above the minumum possible score for each evaluated item (Table 5). No differences in this regard were found between the 2 overdenture types. Ten subjects reported that their eating habits had changed, but other than that, no dramatic changes in subjects' daily lives had occurred following overdenture treatment (Table 6).

DISCUSSION

Much of the information on implant-retained overdentures has been obtained from retrospective studies

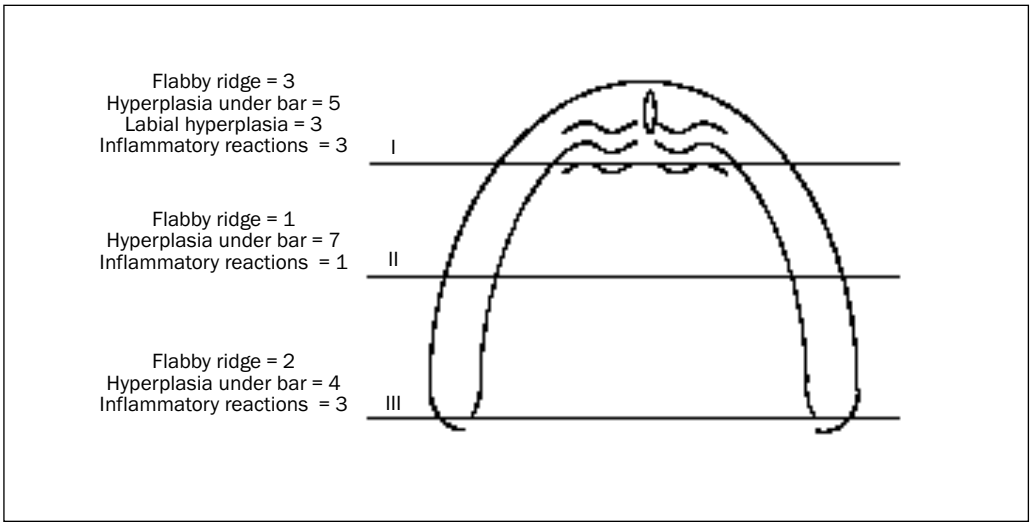

Fig 3 Number of subjects with oral mucosal changes in different regions of the edentulous maxilla. In addition, palatal denture stomatitis was noted in 2 subjects. I = anterior maxilla; II = premolar region; III = molar region.

Table 2 Survival Rate of the Implants

Mo. after placement	No. of subjects	No. of implants*	Implants failed	Implants withdrawn	Cumulative survival rate
0 to 12	16	84	7	0	92%
13 to 24	16	77	0	25	92%
25 to 36	11	52	0	16	92%
37 to 48	8	36	1	19	90%
49 to 60	4	16	0	0	90%
61 to 72	4	16	0	0	90%

*Number of loaded implants in the beginning of the time period.

and data retrieved from patients' chart reviews.[2,4,17–21] Nevertheless, retrospective follow-up examinations without an experimental study design can enhance the objective assessment of subjects' oral status and provide a basis for prospective clinical trials. Prospective studies can seldom guarantee true blind conditions for clinical examinations, whereas in retrospective studies, treatment strategies are usually based only on patients' needs and clinical evaluation is not biased by the expectations for treatment results. Therefore, retrospective follow-up studies can provide important information about different treatment strategies that can be helpful in developing more effective treatment approaches.

In this study, most overdenture wearers were satisfied with their prosthesis, and some reported significant improvement in oral function following implant treatment. In this respect, no differences were seen among the subjects with different overdenture restorations. Subjects were highly motivated to maintain good oral hygiene, and most subjects continued to perform good oral hygiene. Some of the subjects with bar-retained overdentures experienced difficulties in maintaining good oral hygiene, although most of the implants were relatively free of plaque.

Table 3 Number and Location of Loaded Implants According to Type of Attachment

Type of attachment	Incisor	Canine	Premolar	Molar	Total
Bar	3	21	18	12	54
Ball	0	5	11	1	17
Total	3	26	29	13	71

Hyperplasia under bar superstructures and localized inflammatory reactions were the most common mucosal changes. Hyperplasia is a frequent finding in overdenture wearers.[22] It may be avoided with

Table 4 Peri-implant Changes Around Implants Retaining Maxillary Overdentures

Patient	Type of attachment	Bone grafting?	Plaque index*	Sulcus bleeding index†	Pocket depth (mm)	Loss of bone support‡
1	Bar	Yes	0.7 (2.1)	0.9 (1.2)	3.5 (1.1)	0.18 (0.13)
2	Bar	Yes	0.1 (0.3)	0.3 (0.4)	2.0 (0.7)	0.15 (0.08)
3	Ball	No	0.0 (0.0)	0.9 (0.4)	2.0 (0.5)	—
4	Ball	Yes	0.0 (0.0)	0.9 (0.3)	4.1 (1.4)	0.47 (0.19)
5	Ball	Yes	0.0 (0.0)	0.6 (0.5)	5.9 (1.1)	0.38 (0.10)
6	Bar	Yes	0.0 (0.0)	1.0 (1.3)	3.1 (1.4)	0.11 (0.11)
7	Bar	No	0.1 (0.2)	1.4 (1.5)	3.1 (0.9)	—
8	Bar	No	0.0 (0.0)	0.5 (0.5)	2.0 (0.7)	0.25 (0.04)
9	Bar	Yes	0.0 (0.0)	0.5 (0.5)	2.7 (1.3)	0.17 (0.11)
10	Ball	Yes	0.1 (0.4)	0.8 (0.7)	3.1 (1.1)	—
11	Bar	No	0.0 (0.0)	0.0 (0.0)	0.9 (0.4)	0.13 (0.16)
12	Bar	No	1.1 (0.9)	0.5 (0.5)	1.9 (0.8)	0.18 (0.12)
13	Bar	Yes	0.0 (0.0)	0.3 (0.5)	2.8 (1.0)	0.32 (0.05)
14	Bar	No	0.1 (0.3)	0.5 (0.5)	2.5 (0.9)	0.19 (0.06)
15	Bar	Yes	0.1 (0.5)	0.5 (0.5)	2.1 (0.8)	0.19 (0.04)
16	Ball	No	0.4 (0.8)	0.9 (0.3)	2.5 (1.0)	0.21 (0.10)

*Mean ± (SD), according to Silness and Löe.[15]
†Mean ± (SD), according to Mombelli et al.[16]
‡Decrease in the bone level/implant length ratio (mean ± SD) as measured from panoramic radiographs. — = data not available due to poor–quality radiographs.

Table 5 Complaints with Implant-Retained Maxillary Overdenture by Type of Anchorage System

Complaints	Ball (n = 5)	Bar (n = 11)	Significance
Eating complaint score (range 5–20) 1. Denture gets loose while eating 2. Food gets under the denture 3. Chewing is difficult 4. Impairment in tasting 5. Problems with swallowing	5.8 ± 2.2	5.4 ± 1.4	N.S.
Functional complaint score (range 6–24) 1. Denture does not fit well 2. Denture gets loose while speaking 3. Denture gets loose while opening mouth wide 4. Not enough space for the tongue 5. Lip or cheek gets between the teeth 6. Denture rocks	9.4 ± 0.9	10.7 ± 1.6	N.S.
Pain complaint score (range 4–16) 1. Pain while eating hard, soft, or rough food 2. Burning sensation in the mouth	5.0 ± 1.4	4.8 ± 0.8	N.S.
Esthetic complaint score (range 7–28) 1. Size of teeth unsatisfactory 2. Color of teeth unsatisfactory 3. Tooth arrangement unsatisfactory	16.8 ± 2.3	13.8 ± 4.1	N.S.
Overall complaint score (range 22–88)	39.0 ± 5.2	34.8 ± 10.7	N.S.

Each item was evaluated on a 4-point rating scale, with 0 indicating no problems and 3 indicating severe problems.
Unpaired 2-tailed *t* test.

Table 6 Affirmative Answers to Questions About the Effect of Overdenture Treatment on Subjects' Daily Life

Question	Bar	Ball	Total
Have you noticed any unwanted outcomes from the implant treatment?	3/11	0/5	3/6
Have your family members or friends noticed any changes in your behavior since the implant treatment?	6/11	4/5	10/16
Have your eating habits changed since receiving the implant-retained dentures?	6/11	4/5	10/16
Has your self-confidence increased since receiving the implant-retained dentures?	1/11	1/5	2/16
Are more friends interested in implant treatment after your experiences?	7/11	3/5	10/16
Do you pay more attention to your oral hygiene since the implant treatment?	6/11	4/5	10/16
Do you have difficulties with your oral hygiene since the implant treatment?	3/11	0/5	3/16

Differences between groups were not significant.

careful oral hygiene, but a successful result cannot be assured if the space between the bar and the oral mucosa is narrow. This is often the case in the maxilla, since short abutments are usually placed to avoid bulky overdenture restorations.

The cause of the loose abutments was not known. Some of the abutments may have become loose while removing the superstructures, or the flexibility of the superstructures could have caused the abutments to loosen. Most of the superstructures were fabricated with commercially available 1.9-mm round bars. It can be speculated that, if the distance between the abutments is long enough, conventional bars are no longer rigid and loading forces can cause dampening effects for the abutments. Of interest was the observation that no inflammatory reactions were seen around the gingival margins of the loose abutments.

In this study, the cumulative implant survival rate was slightly higher than in previous reports on maxillary overdentures.[4,17,18] Most of the present subjects had been treated within 2 years of the clinical examination. At that time, the outcome of previous studies on implant-retained maxillary overdentures was already available. In the study subjects, some of the risk factors for implant failures (eg, the use of short implants) could therefore be avoided. None of the implants placed were shorter than 12 mm. This is obviously one reason for the lower implant failure rate among these subjects.

Standardized intraoral radiographs were not available at baseline; thus, marginal bone loss was necessarily evaluated from panoramic radiographs. Because the measurements made from panoramic radiographs cannot be reliably compared, the ratio between bone height and implant length was used to describe bone support for implants. Although this is certainly not the most accurate method, the change in the ratio provides a rough estimate of loss of bone support. In practice, however, changes in implant bone support are frequently evaluated from panoramic radiographs.

In a retrospective study, multiple variables may affect treatment results. Therefore, ideally, multivariate analysis would be used to identify the most important factor for adverse treatment outcome. In this study, sample size was far too small for such an analysis. Therefore, it was impossible to make any statistical evaluation concerning the factors related to the decrease in implant bone support. The number of implants would possibly have been sufficient for multivariate analysis, but the analysis could not be performed at the implant level because multiple implants in the same individual were not statistically independent.

Mean values describing the loss of bone support appeared to be greater in subjects with ball attachments. Again, because of the limited number of subjects with ball-retained overdentures, this difference did not reach statistical significance. However, the finding is in agreement with previous reports about splinted and unsplinted implants retaining maxillary overdentures.[11,23] In patients with advanced residual ridge resorption, denture flanges do not completely protect the denture against horizontal forces, which can create unfavorable loading conditions for the implants. With bar-retained restorations, a space between the bar and the clips facilitates small vertical and horizontal movements of the denture. When ball attachments are used, the spaces between balls and matrices are smaller, and denture movements are limited. It has been speculated, however, that in the oral environment, the space between the bar and the clips will soon be lost.[24] However, in the present subjects, space was still present with 77% of the clip retainers. Differences in loading conditions could therefore be one reason for the greater bone loss seen around the unsplinted implants. Regarding the loading conditions, occlusion and articulation play an important role. In this study, most subjects had

an overdenture or complete denture in the mandible, and their occlusion was designed according to the lingualized occlusion concept. In those subjects, eccentric forces were controlled during the articulation. A natural dentition in the opposing jaw limits the possibilities for achieving a fully balanced articulation, so canine-guided articulation is normally used in these patients. With the limitations of this study, it was impossible to evaluate the effect of occlusion on implant failure or loss of bone support.

The loss of bone support around unsplinted implants can also be related to the bone conditions where they are placed. Ball attachments were used in situations where either the number or location of implants did not facilitate the fabrication of bar superstructures. It has been clearly shown that implant failures are more frequent when quantity or quality of bone is poor.[6,13,22]

CONCLUSION

Although some bone loss was seen in most subjects, in only 1 patient with a ball-retained overdenture did the loss of bone support exceed half the length of the implant. Because of the limited number of subjects in this study, it was not possible to make any recommendations as to which attachment system is more preferable for maxillary overdentures. More mucosal changes were seen with bar superstructures. However, an increased possibility of peri-implant bone loss should be considered when unsplinted implants are used.

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:385–416.
2. Chan MFW-Y, Howell RA, Cawood JI. Prosthetic rehabilitation of the atrophic maxilla using pre-implant surgery and endosseous implants. Br Dent J 1996;181:51–58.
3. Geertman ME, Boerrigter EM, van Waas MAJ, van Oort RP. Clinical aspects of a multicenter clinical trial of implant-retained mandibular overdentures in patients with severely resorbed mandibles. J Prosthet Dent 1996;75:194–204.
4. 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.
5. 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.
6. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: A 5-year analysis. J Periodontol 1991; 62:2–4.
7. Ulm CW, Solar P, Gisellmann B, Malejka M, Watzek G. The edentulous maxillary alveolar process in the region of the maxillary sinus: A study of physical dimension. Int J Oral Maxillofac Surg 1995;24:279–282.
8. Bergendal T, Engquist B. Implant-supported overdenutres: A longitudinal prospective study. Int J Oral Maxillofac Implants 1998;13:253–262.
9. Hürzeler MB, Kirsch A, Ackermann K-L, Quinones CR. Reconstruction of the severely resorbed maxilla with dental implants in the augmented maxillary sinus: A 5-year clinical investigation. Int J Oral Maxillofac Implants 1996;11: 466–475.
10. Williamson RA. Rehabilitation of the resorbed maxilla and mandible using autogenous bone grafts and osseointegrated implants. Int J Oral Maxillofac Implants 1996;11:476–488.
11. 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.
12. Albrektsson T, Sennerby L. State of the art in oral implants. J Clin Periodontol 1991;18:474–481.
13. Albrektsson T, Zarb GA, Worthington P, Eriksson RA. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
14. Listgarten MA. Soft and hard tissue response to endosseous dental implants. Anat Rec 1996;245:410–425.
15. Silness J, Löe H. Periodontal disease in pregnancy. Correlation between oral hygiene and periodontal condition. Acta Odontol Scand 1964;22:121–135.
16. Mombelli A, Van Oosten MAC, Schürch E, Lang NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987;2: 145–151.
17. Jemt T, Book K, Lindén B, Urde G. 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 checkup. Int J Oral Maxillofac Implants 1992;7:162–167.
18. Jemt T, Book K, Karlsson S. Occlusal force and mandibular movements in patients with removable overdentures and fixed prostheses supported by implants in the maxilla. Int J Oral Maxillofac Implants 1993;8:301–308.
19. 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.
20. Jemt T, Lekholm U. Implant treatment in edentulous maxillae: A 5-year follow-up report on patients with different degrees of jaw resorption. Int J Oral Maxillofac Implants 1995;10:303-311.
21. 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.
22. Jemt T, Chai J, Harnett J, Heath MR, Hutton JE, Johns RB, et al. A 5-year prospective multicenter follow-up report on overdentures supported on osseointegrated implants. Int J Oral Maxillofac Implants 1996;11:291–298.
23. 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.
24. 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.