Within-Subject Comparison of Two Rigid Bar Designs Connecting Two Interforaminal Implants: Patients' Satisfaction and Prosthetic Results

Regina Mericske-Stern, Prof. Dr. med. dent.;* Dieter Probst, Dr. med. dent.;†
Fritz Fahrländer, Dr. med. dent.;‡ Marc Schellenberg, Dr. med. dent.§

ABSTRACT

Background: There is evidence for the superiority of two-implant overdentures over complete dentures in the mandible. Various anchorage devices were used to provide stability to overdentures. The aim of the present study was to compare two designs of a rigid bar connecting two mandibular implants.

Materials and Methods: Completely edentulous patients received a new denture in the maxilla and an implant-supported overdenture in the mandible. They were randomly allocated to two groups (A or B) with regard to the bar design. A standard U-shaped bar (Dolder bar) was used connecting the two implants in a straight line. For comparison, precision attachments were soldered distal to the bar copings. Group A started the study with the standard bar (S-bar), while group B started with the attachment-bar (A-bar). After 3 months, they had to answer a questionnaire (visual analogue scale [VAS]); then the bar design was changed in both groups. After a period of another 3 months, the patients had to answer the same questions; then they had the choice to keep their preferred bar. Now the study period was extended to another year of observation, and the patients answered again the same questionnaire. In vivo force measurements were carried out with both bar types at the end of the test periods. The prosthetic maintenance service carried out during the 6-month period was recorded for both bar types in both groups. Statistical analysis as performed with the SPSS statistical package (SPSS Inc., Chicago, IL, USA).

Results: Satisfaction was high in both groups. Group B, who had entered the study with the attachment bar, gave slightly better ratings to this type for four items, while in group A, no differences were found. At the end of the 6-month comparison period, all but one patient wished to continue to wear the attachment bar. Prosthetic service was equal in groups A and B, but the total number of interventions is significantly higher in the attachment bar. Force patterns of maximum biting were similar in both bar designs, but exhibited significantly higher axial forces in the attachment bar.

Conclusions: Both bar designs provide good retention and functional comfort. High stability appears to be an important factor for the patients' satisfaction and oral comfort. Rigid retention results in a higher force impact and appears to evoke the need for the retightening of occlusal screws, resulting in more maintenance service.

KEY WORDS: bar retention, implants, mandibular overdentures, patient's satisfaction

INTRODUCTION

Nowadays, there is sufficient evidence that overdentures supported by a few, mostly two, intraforaminal implants are superior to complete dentures.[1,2] In several studies, it was demonstrated that patients gave high ratings to chewing function, hygiene procedures, and overall comfort with implant-supported overdentures.[3–5] Implant-supported mandibular overdentures, in comparison with conventional complete dentures, may contribute to quality of life.[6] Patients' assessment of treatment outcome with mandibular overdentures may be equal to that of fixed prostheses,

*Director and chair, Department of Prosthodontics, School of Dental Medicine, University of Bern, Switzerland; †private practice, Derendingen, Switzerland; ‡private practice, Biel, Switzerland; §private practice, Freiburg, Switzerland

Reprint requests: Prof. Dr. Regina Mericske-Stern, Department of Prosthodontics, University of Bern, 3010 Bern, Switzerland; e-mail: regina.mericske@zmk.unibe.ch

DOI 10.1111/j.1708-8208.2008.00109.x

and it appears that patients – if they have the choice – do not automatically select the fixed prostheses.[3] Various authors concluded that two-implant overdentures for the mandible should become the standard of care.[7] Another question is which is the best choice for overdenture anchorage on two intraforaminal implants. Basically, this may be considered from four different points of view: (1) the patient's individual needs and perception of denture stability; (2) the biomechanical considerations regarding functional loads onto the implants and surrounding soft tissue; (3) the direct cost for the different anchorage systems; and (4) the technical problems and maintenance service provided that will result in indirect costs. There is some controversy in the literature regarding these subjects. While clinicians often suggested the use of a resilient retention mechanism, which means a round clip bar or single-ball anchors, no study has ever reported on the deleterious effect of a rigid bar design. A review could not reveal differences in treatment outcomes for different attachment systems.[8]

Results of force measurements in vivo also indicate that maximum biting force increase with two mandibular implants. Chewing performance seems to improve if complete mandibular dentures are connected to two implants,[9,10] and biting forces with implant overdentures were higher than with complete dentures but did not reach forces of fully dentate subjects. Furthermore, maximum biting forces appear to be a good parameter for chewing forces and chewing efficiency.[11]

The assessment of technical problems and maintenance service for overdentures connected to mandibular implants does not lead to clear conclusions. Service needed appears to be quite high.[12] A confounding factor is that criteria to assess complications, maintenance service, and technical failures are used differently in different studies and are not well defined. It is not known which type of overdenture retention mechanism would patients select if they had the choice. The reports on complication rates show that patients often asked for retightening of the female parts, which can be an indicator that they wish better stability and retention.

The aim of the present study was to assess patients' satisfaction and the prosthetic aspects of a rigid retention mechanism provided by two different bar designs for overdenture support.

MATERIALS AND METHODS

Patients

During a 1-year period, edentulous patients wearing complete dentures who sought treatment with intraforaminal implants at the Department of Prosthodontics were evaluated and recruited for this study. Selection criteria were:

1. at least 3 years of edentulousness
2. wearing complete dentures in both jaws
3. no smoking
4. fair health conditions as follows:
   - no diabetes dependent on insulin
   - no bisphosphonates
   - no irradiation or chemotherapy
   - no long-term intake of steroids
   - no anticoagulation, but thrombocyte aggregation inhibitors were accepted
   - no history of heart attack/CVI during the last 12 months; cardiovascular problems, high or low blood pressure, if well controlled by medications, were not excluded (Digoxin, beta-blocker)
5. no history of previous implant failure
6. age between 50 and 75 years
7. sufficient bone height and width to accommodate two implants of minimum length (8 mm) and standard diameter (4.1 mm) without grafting procedures, membranes, or additional surgery measures, that is, bone quantity

Panorama and lateral radiographs were obtained from all patients to calculate bone height and width. The selected patients consented to participate in the study and signed the informed consent, but all patients covered, like regular patients, the costs for the treatment themselves.

Study Design

After a 1-year period of recruiting, 20 Caucasian patients – 12 men and 8 women – were available and randomly attributed to two groups of 10 patients each with regard to the bar design. Their age ranged between 52 and 74 years. All patients were then operated under local anesthesia by one investigator or under his supervision and received two one-stage implants (Straumann AG, Waldenburg, Switzerland) with an SLA® surface, according to a standard protocol. The length of the implants varied between 8 and 12 mm. A healing period

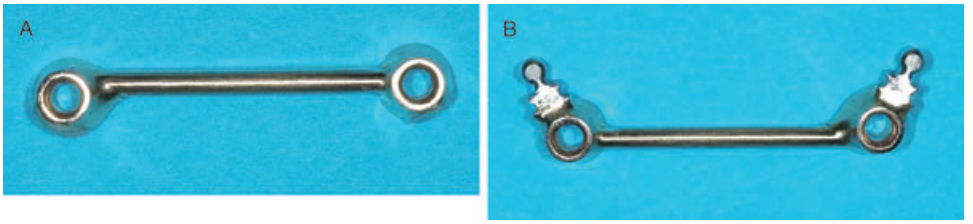

Figure 1 *A*, Rigid standard bar (S-bar). *B*, Bar with soldered attachments in distal position (A-bar).

of 2 months was maintained with the old dentures in situ. The implants were kept free from contact with the dentures and were not connected; then the prosthodontic treatment was initiated and all patients received a new complete denture in the upper jaw and an implant-supported overdenture connected to a rigid bar in the lower jaw. Group A received a standard rigid bar design (U-shaped Dolder bar) connecting both implants in a straight line (S-bar). Group B received the same bar design but with two additional precision attachments (SG attachments; Cendres Métaux, Biel, Switzerland) soldered in distal position to the gold copings of the bar (A-bar) (Figure 1, A and B). The surgical and prosthodontic treatment covered a 4-month period; then the patients of both groups had to wear the dentures/overdentures for a 3-month period. At the end of this first test period, they answered a questionnaire and underwent force measurements; then the bar design was changed. In group B, the distal attachments were removed, while in group A, these were added. In both groups, the mandibular dentures were adjusted accordingly. Again, the dentures had to be worn by the patients of both groups for 3 months. At the end of this second test period, they answered the questionnaire again and underwent force measurements. Now the patients had the option to keep the bar type of their choice and continued to use their dentures for another 12-month period, after which they answered again the questionnaire.

Eight-Item Questionnaire (Visual Analogue Scale [VAS])

The patients had to assess their function and handling of the dentures. A questionnaire was used with the following items:

1. overall satisfaction
2. comfort of wearing dentures
3. speech and phonation
4. chewing ability
5. metallic taste
6. stability and retention of mandibular dentures
7. handling of the dentures (insertion, removal)
8. ease of hygiene procedure

The answers of both groups were recorded by means of a VAS of 100 mm at the end of each 3-month period. After this 6-month period, the patients continued to wear the overdentures with the bar of their choice for another 12 months; then all patients were recalled to answer the questionnaire again. Some further questions were directly addressed to the patients in an open interview. These were related to their choice of bar, subjective experience during the past year, mastication, retention, and current hygiene procedures.

Three-Dimensional Force Measurements In Vivo

As described in previous studies,[13–15] force measurements in vivo were performed with piezoelectric transducers mounted directly onto the implants. Static and functional forces were measured simultaneously on both implants in three dimensions (Figure 2, A and B). These were (1) maximum occlusal force (MOF) when biting in centric occlusion and (2) maximum forces during unilateral biting on a bite plate (MF-B-Plate) (see Figure 2, C and D). The registered forces on the bite plate itself represent a value for simple axial biting. Simultaneous with the force registration with the bite plate, three-dimensional forces were registered on the ipsilateral and contralateral implants. The force measurements were performed with a duplicate of the original overdentures as described previously.[13–15] In one session, the forces were registered with the attachment bar. In another session, the same measuring protocol was applied after the removal of the precision attachments. All biting tasks were repeated five times, and the mean values were calculated. The measured values in the

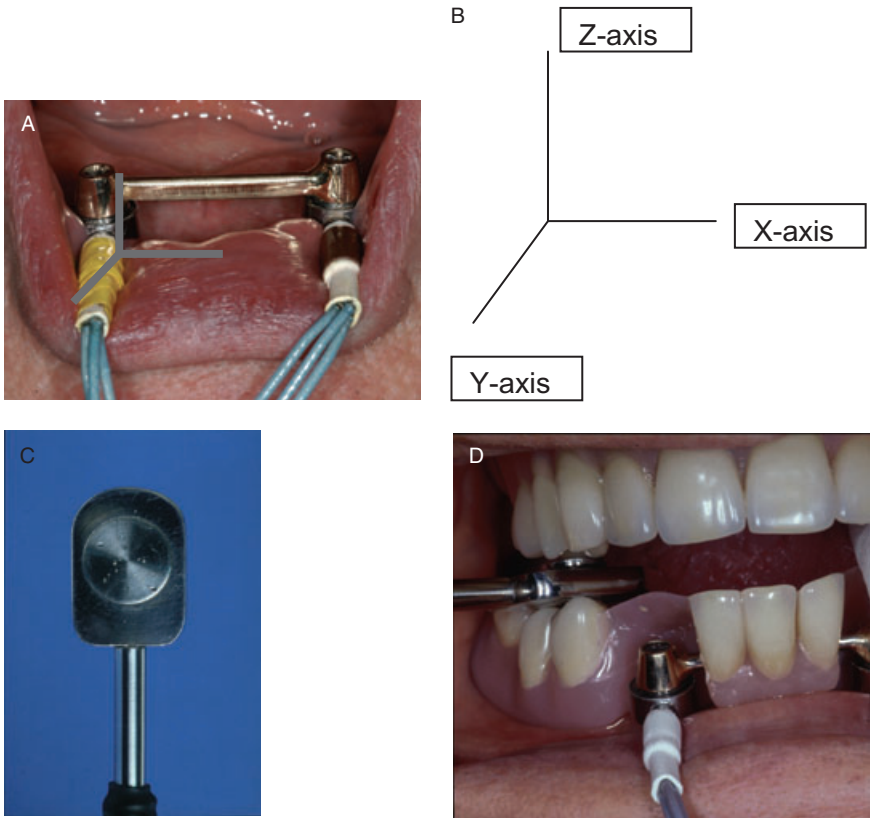

Figure 2 *A*, Force transducers mounted on implants. *B*, Schematic view of three-dimensional measurements. *C*, Bite plate. *D*, Clinical view with three-dimensional piezoelectric transducer and bite plate in situ.

present studies could be compared with those of previous results obtained with the same measuring protocol.

Prosthetic Maintenance

During the 6-month study period, all patients had scheduled appointments once a month. All prosthetic service, complications, and repairs were registered. The classification into three categories was used as described previously.[16] The first category is related to the implant/abutment/bar assembly, the second category contains repairs of the dentures, and the third adjustments of the dentures as follows:

Anchorage device:

1. abutment loosening
2. loosening or loss of occlusal screw
3. broken loose lost female retainers
4. retightening of female retainers
5. attachment fracture

Repair of denture:

6. denture base resin fracture
7. fracture of teeth
8. fracture of cast framework
9. change of denture design

Adjustments of denture:

10. hyperplasia under bar
11. Relining of overdenture
12. occlusal adjustment of overdenture
13. aesthetic problems
14. excessive wear of teeth
15. hyperplasia under attachment

A differentiation was made between hyperplasia under the bar segment and under the precision attachment.

Costs of Treatments

All patients had to cover the costs for the treatment themselves, that is, the placement of the implants, the fabrication of the prostheses, and the bar. The mandibular two-implant overdentures in general is considered to be a low-cost implant therapy as compared with fixed prostheses. The average costs at the department are comparable with the fees in a general private practice.

The change of the bars were not charged. The bar with the attachments increased the costs by approximately 10%; thus, the treatment fees were calculated according to patient's final choice of the bar design. As a compensation for their participation in the study, the patients had free access to the maintenance service provided by the dental hygienist during 1 year after the end of the study.

Statistical Analysis

The SPSS statistical package (SPSS Inc., Chicago, IL, USA) was used.

For statistical analysis of the questionnaire (VAS, 10 mm), the Wilcoxon's test was used: Wilcoxon matched-pairs signed-rank for pairwise testing within groups and Wilcoxon–Mann–Whitney *U* test for comparisons between groups.

Means of maximum forces were calculated from all registered biting tasks. Parametrical testing (*t*-test) adjusted with the equation of Bonferroni was applied for comparisons of means. Pearsons' correlation coefficient was calculated to describe the correlation between mean maximum biting force and the maximum biting force on the bite plate.

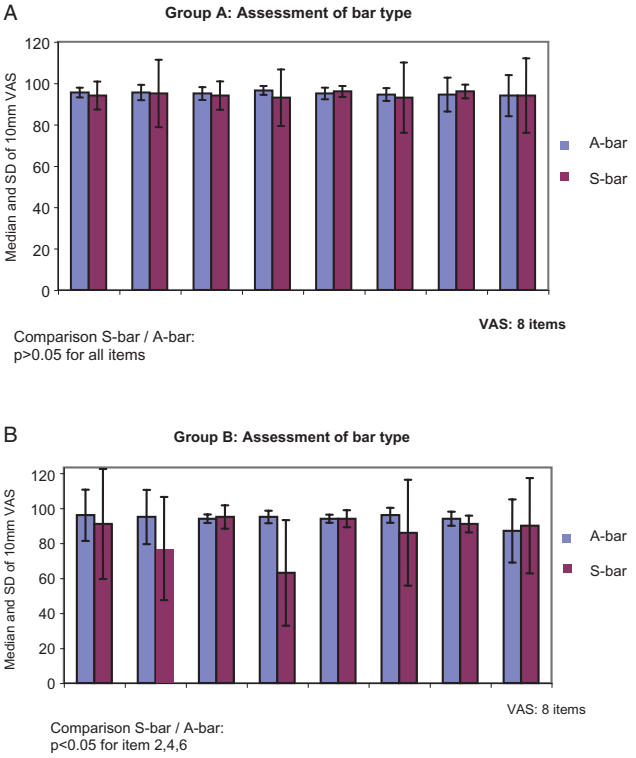

Figure 3 *A* and *B,* Results from the eight-item questionnaire (visual analogue scale [VAS]) with the A-bar and the S-bar for both groups.

RESULTS

No implant was lost during the healing phase or during the entire study period. There was no patient who discontinued to wear the dentures or dropped out from the study for any reason.

VAS

Figure 3, A and B show the results of the questionnaire for both bars. Group A, which first received the S-bar without the precision attachments, exhibited no significant difference in the ratings between both bar types. The mean values were all over 9 mm for both bars. The standard deviations were slightly larger for denture comfort, chewing comfort, stable retention, and hygiene procedure with the S-bar. Group B, which started with the A-bar, reached mean values of ≥9 mm for the S-bar. However, these ratings for the S-bar were significantly lower for items 2, 4, and 6, that is, comfort with denture, chewing ability, and stable retention ($p < .01$ and .05) as compared with the A-bar. If groups A and B were matched, the overall ratings on the VAS questionnaire revealed significantly higher values for the A-bar related to items 4 and 6 (chewing ability and stability of the denture, $p < .05$). At the end of the study, all but one patient made the choice to continue with the A-bar. The completion of the questionnaire after 1 year resulted in values of >90 mm by all patients for all questions, except for three answers of three patients, which were related to chewing function. When the patients were directly asked why they had chosen to continue with the A-bar, 80% of the patients answered that they did so because of better retention and 50% added that they did so because of better chewing ability. However, 64% admitted that initially, they had some handling problems. Forty percent mentioned some food impaction under the prostheses, and 22% mentioned some problems with hygiene procedures.

Force Measurements

Table 1 shows the mean values in the vertical dimension obtained from the maximum force measurements (MOF) in both bar types. The maximum force magnitudes in the axial direction had a large individual range of 45 to 180 N with the S-bar and a range of 65 to 250 N with the A-bar. The mean maximum value was significantly higher when measured with the A-bar ($p < .01$) in

TABLE 1 Mean Maximum Bite Forces In Vivo in Axial Direction

Bar Type	MOF	MF-B-Plate	Biting Task with Bite Plate		Pearson's Correlation	
			Ipsilateral	Contralateral	Ipsilateral	Contralateral
Current study						
S-bar	68.3 ± 34	156.2 ± 41	36.4 ± 27	2.0 ± 2	n.s.	n.s.
	{$p < .01$	{$p < .001$				
A-bar	125.7 ± 46	169.6 ± 35	142.2 ± 41	0.0	$p < .01$	n.s.
Previous studies						
Rigid bar*	80.6 ± 41	129.3 ± 26	38.7 ± 21	16.1 ± 14		
Rigid bar extensions	96.2 ± 62	171.6 ± 47	149.3 ± 62	13.3 ± 10		
Telescopes	114.6 ± 86	193.4 ± 80	144.5 ± 69	14.7 ± 25		

*Corresponds to the S-bar (identical design).
MOF = maximum occlusal force (left and right implant pooled); MF-B-Plate = maximum forces measured on the bite plate; n.s. = not significant.

the axial force direction. MOF in transverse force directions, as shown by Table 2, was lower in both bar types, but again statistically different. The mean maximum forces measured on the bite plate (MF-B-Plate) was around 150 N, that is, between 120 and 180 N measured with the S-bar and 140 and 180 N measured with the A-bar, respectively. However, force magnitudes measured simultaneously on the ipsilateral implant were

TABLE 2 Mean Maximum Bite Forces In Vivo in Transverse Direction

y-Axis

Bar Type	MOF		Biting Task with Bite Plate		
			Ipsilateral		Contralateral
Current study					
S-bar	21.1 ± 4		20.9 ± 12		10.8 ± 6
		{$p < .05$		{$p < .05$	
A-bar	43.7 ± 8		56.1 ± 18		6.6 ± 4
Previous studies					
Rigid bar*	23.0 ± 9		27.5 ± 10		8.7 ± 4
Rigid bar extensions	15.9 ± 13		49.3 ± 17		8.7 ± 6
Telescopes	23.4 ± 16		53.7 ± 31		11.7 ± 9

x-Axis

Bar Type	MOF		Biting Task with Bite Plate		
			Ipsilateral	Contralateral	
Current study					
S-rigid bar	7.5 ± 2		6.6 ± 4	13.1 ± 5	
		{$p < .05$			{$p < .05$
A-bar	15.9 ± 8		7.6 ± 5	6.0 ± 3	
Previous studies					
Rigid bar*	23.6 ± 10		5.7 ± 2	15.9 ± 6	
Rigid bar extensions	12.1 ± 6		9.7 ± 6	12.7 ± 7	
Telescopes	17.1 ± 9		20.6 ± 16	13.0 ± 9	

*Corresponds to the S-bar (identical design).
MOF = maximum occlusal force.

significantly higher in the A-bar ($p < .001$) as compared with the S-bar in the z- and y-axes ($p < .05$), while a significantly higher value on the contralateral implant was observed for the S-bar in the x-axis. In both bars, the values of the contralateral implant were close to 0 in the z-axis. Figure 4 shows the mean values of all patients from five repeated biting tasks with the bite plate in all three dimensions. The values of mean maximum biting forces for all biting tasks were comparable with the findings in previous studies with the same measuring protocol. The respective figures are shown in Tables 1 and 2.

Prosthetic Maintenance

The overall number of maintenance interventions and service provided was equal to 34 in group A and to 35 in group B, respectively. Table 3 gives an overview of the maintenance performed for both bar designs irrespective of the patient groups. Here, more interventions were counted for the A-bar, namely, 39 as compared with 30 for the S-bar ($p < .05$). Differences were observed with regard to items 2, 3 and 15.

DISCUSSION

From this clinical study, it can be concluded that edentulous patients are satisfied with two-implant-supported mandibular overdentures in spite of the fact that the study patients had to afford the costs themselves. Thus, a possible effect that patients who feel privileged to be accepted for a study and get treatment for free might quote more positively their treatment outcome was eliminated.

The ratings with the VAS were high for both bar designs and only minor differences were observed in the group that started with the attachment bar first. This is attributed to the effect of the study design. Group B changed from a loose complete denture to a rigidly supported overdenture with the A-bar. When they switched to the simple S-bar, they may have felt some diminution in the stability without the attachments. This was not the case in group A, who received the S-bar first. This bar provided good stability after a loose complete denture and led immediately to high ratings. When they switched to the A-bar, it was rarely possible to further increase the ratings. Items related to denture comfort, chewing ability, and denture retention implies that stability of the denture is an important aspect. One crossover study compared fixed mandibular prostheses with long-bar overdentures, opposing a complete denture.[3] The choice of the patients was mostly based on ease of handling and not on functional aspects such as chewing or denture retention. However, it has to be considered that a long bar might provide functional stability and retention that are comparable with that of fixed prostheses. If chewing function of overdentures with a long bar or single-ball anchors were compared, some differences were observed in the functional patterns. With both types of prostheses, the patients adapted their chewing patterns.[17] In spite of an increase in cost by 10%, in the present study with short anterior bars, all but one patient chose the attachment bar. This means that some difference in the perception of stability was felt, and good retention appeared to be important for the patients as confirmed by the questionnaire. The answers the patients gave 1 year after the end of the study can be interpreted in this sense and lead to such conclusions.

Force measurements on interforaminal implants in vivo performed with resilient and rigid attachment revealed some differences of mean maximum force magnitudes, with significantly higher values along the axial implant axis (z-axis)[13–15,18] in the presence of a rigid retention mechanism. Minor differences with lower force magnitudes were found in transverse force directions too.

The present findings show significantly higher axial forces in the presence of attachments as compared with the S-bar. These results are very much in keeping with previous results that exhibited higher forces with rigid telescope retention and rigid bars.[13] The experiment with unilateral biting shows that the splinting effect, that is, the distribution of axial forces onto both implants by means of the bar mostly does not occur, particularly with the A-bar. The values were 0 or close to it. This again was observed in previous studies with telescopes and extension bars.[13,14,18] The impact of this observation on the clinical performance of the implant surrounding bone and remodeling processes is not known, but no negative outcome has ever been reported. One study reported on splinted (bars) and unsplinted (ball anchors) interforaminal implant-supporting overdentures. No differences in long-term outcomes were observed.[19] In the present study, a tendency to higher biting forces was observed with the A-bar, which could explain the slightly better ratings on the VAS for the items denture comfort, chewing ability, and denture stability.

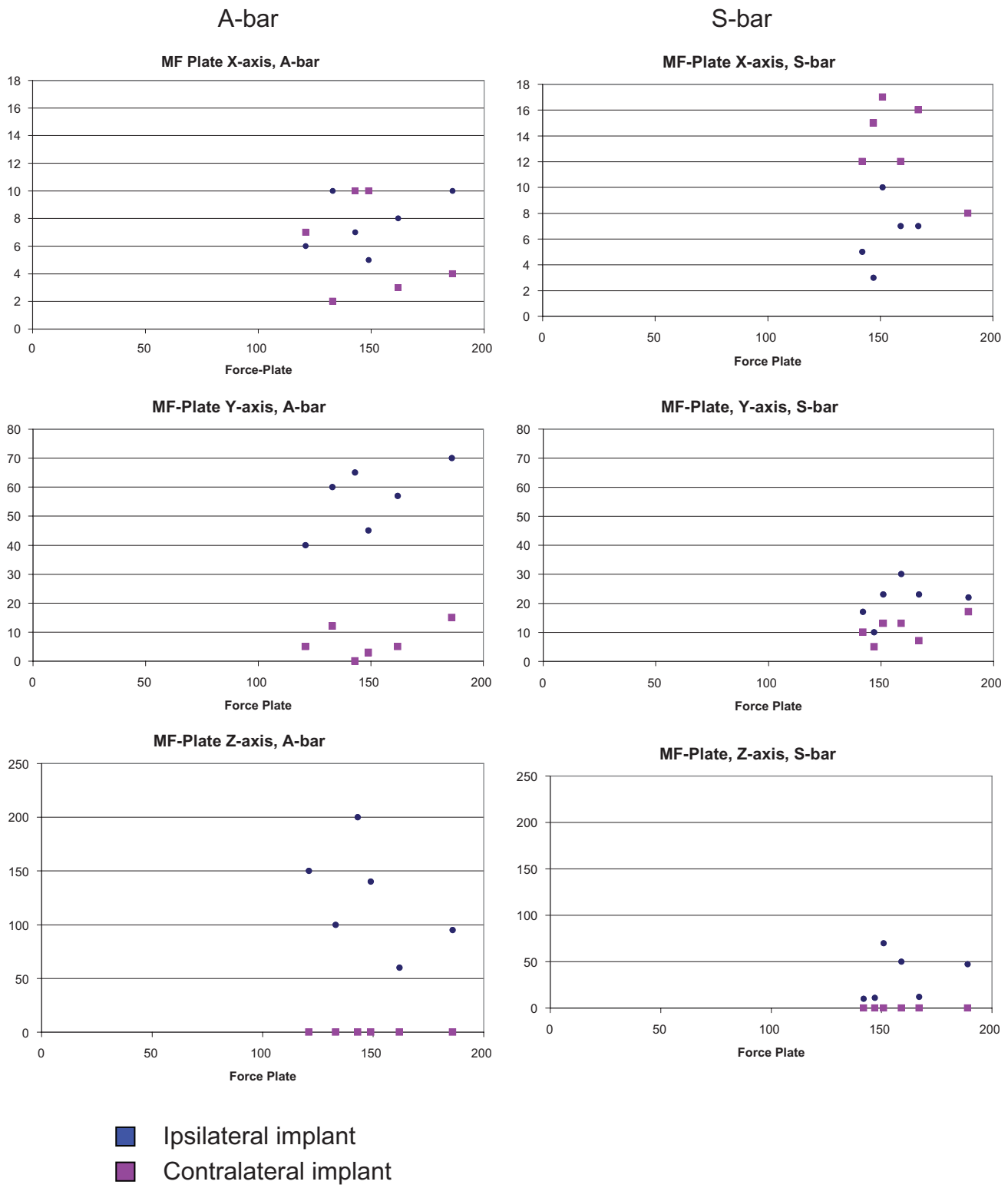

Figure 4 Biting task with the bite plate: the figures exhibit the mean maximum forces for the ipsilateral and contralateral implants in all three dimensions with either the S-bar or the A-bar. Five biting tasks were performed.

TABLE 3 Prosthetic Maintenance Service

	Group A Bar Type		Group B Bar Type		Total Bar Type	
	S	A	S	A	S	A
Anchorage device						
1. Corrosion	2	2	2	2	4	4
2. Abutment loosening	4	4	1	6	5	10
3. Occlusal screw retightening	2	4	1	3	3	7
4. Retainer problems	2	0	0	0	2	0
5. Bar/attachment fracture	0	0	0	0	0	0
Repair of dentures 6.–9.	No repairs in either group					
Adjustments						
10. Sore spots	0	2	5	1	5	3
11. Relining	1	0	0	0	1	0
12. Occlusal adjustment	0	2	3	3	3	5
13. Aesthetic problems	0	0	0	0	0	0
14. Excessive tooth wear	0	0	0	0	0	0
15. Hyperplasia under bar	2	7	5	3	7	10
Total	13	21	17	18	30	39

The overall number of prosthetic maintenance service was identical in groups A and B and typical for overdentures. Slightly more service was needed for the A-bar because of hyperplasia underneath the precision attachment and more frequent retightening of screws and abutments. The latter findings can be attributed to higher force impact with the A-bar, which might be a factor of screw loosening. Furthermore, the high rigidity of the A-bar may be more sensitive to proper handling, proper seating of the dentures, and occlusal contact situation. For both dentists and patients, a certain learning curve with the A-bar may be taken into account. One study observed more problems with a bar as compared with single-ball anchors.[20] However, in this study, round clip bars had been used. Another study with long-term observation of rigid and resilient retention devices found more problems with resilient ball anchors and clip bars as compared with rigid bars. These rigid bars had the same design as the standard bar in the present study. A significant number of ball anchors and clip bars were changed to rigid bars during the observation period.[16] Altogether, only few studies deal with the comparison of prosthetic maintenance related to specific designs of retention devices. In the present study, it was found that within the first year after the end of the study, this problem of retightening disappeared, although all patients except one now had the A-bar for overdenture retention. It was often reported that initially after delivery of the dentures, complications were more frequent than in the following years,[21] and that they eventually disappeared.

CONCLUSION

From this crossover study, it is confirmed that satisfaction with implant overdentures in the mandible is high. Patient's demands for proper function seem to be fulfilled. The comparison between both bar types revealed that service provided because of screw loosening was higher with the attachment bar than with the simple rigid bar. However, patients seem to perceive better retention and stability if attachments are soldered to the rigid bar. Furthermore, maximum biting forces tend to increase. This may explain why most patients choose the attachment bar in spite of higher initial costs.

REFERENCES

1. Awad MA, Lund JP, Shapiro SH, et al. Oral health status and treatment satisfaction with mandibular implant overdentures and conventional dentures: a randomized clinical trial in a senior population. Int J Prosthodont 2003; 16:390–396.
2. Strassburger C, Kerschbaum T, Heydecke G. Influence of implant and conventional prostheses on satisfaction and quality of life: a literature review. Part 2: qualitative analysis and evaluation of the studies. Int J Prosthodont 2006; 19:339–348. (ReviewReview)
3. Feine JS, Maskawi K, de Grandmont P, Donohue WB, Tanguay R, Lund JP. Within-subject comparisons of implant-supported mandibular prostheses: evaluation of masticatory function. J Dent Res 1994; 73:1646–1656.
4. de Grandmont P, Feine JS, Taché R, et al. Within-subject comparisons of implant-supported mandibular prostheses: psychometric evaluation. J Dent Res 1994; 73:1096–1104.
5. Allen F, McMillan A. Food selection and perceptions of chewing ability following provision of implant and conventional prostheses in complete denture wearers. Clin Oral Implants Res 2002; 13:320–326.
6. Heydecke G, Locker D, Awad MA, Lund JP, Feine JS. Oral and general health-related quality of life with conventional and implant dentures. Community Dent Oral Epidemiol 2003; 31:161–168.
7. Feine JS, Carlsson GE. Implant overdentures. The standard of care for endetulous paitents. Chicago, IL: Quintessence, 2003.

8. Sadowsky S. Mandibular implant-retained overdentures: a literature review. J Prosthet Dent 2001; 86:468–473.
9. van Kampen FM, van der Bilt A, Cune MS, Fontijn-Tekamp FA, Bosman F. Masticatory function with implant-supported overdentures. J Dent Res 2004; 83:708–711.
10. Fontijn-Tekamp FA, Slagter AP, van't Hof MA, Geertman ME, Kalk W. Bite forces with mandibular implant-retained overdentures. J Dent Res 1998; 77:1832–1839.
11. Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, et al. Biting and chewing in overdentures, full dentures, and natural dentitions. J Dent Res 2000; 79:1519–1524.
12. Chaffee NR, Felton DA, Cooper LF, Palmqvist U, Smith R. Prosthetic complications in an implant-retained mandibular overdenture population: initial analysis of a prospective study. J Prosthet Dent 2002; 87:40–44.
13. Mericske-Stern R, Piotti M, Sirtes G. 3-D in vivo force measurements on mandibular implants supporting overdentures. A comparative study. Clin Oral Implants Res 1996; 7:387–396.
14. Mericske-Stern R. Force distribution on implants supporting overdentures: the effect of distal bar extensions. A3-D in vivo study. Clin Oral Implants Res 1997; 8:142–151.
15. Mericske-Stern R. Three-dimensional force measurements with mandibular overdentures connected to implants by ball-shaped retentive anchors. A clinical study. Int J Oral Maxillofac Implants 1998; 13:36–43.
16. Dudic A, Mericske-Stern R. Retention mechanisms and prosthetic complications of implant-supported mandibular overdentures: long-term results. Clin Implant Dent Relat Res 2002; 4:212–219.
17. Tang L, Lund JP, Taché R, Clokie CM, Feine JS. A within-subject comparison of mandibular long-bar and hybrid implant-supported prostheses: evaluation of masticatory function. J Dent Res 1999; 78:1544–1553.
18. Duyck J, Van Oosterwyck H, Vander Sloten J, De Cooman M, Puers R, Naert I. In vivo forces on oral implants supporting a mandibular overdenture: the influence of attachment system. Clin Oral Investig 1999; 3:201–207.
19. Naert I, Alsaadi G, van Steenberghe D, Quirynen M. A 10-year randomized clinical trial on the influence of splinted and unsplinted oral implants retaining mandibular overdentures: peri-implant outcome. Int J Oral Maxillofac Implants 2004; 19:695–702.
20. Gotfredsen K, Holm B. Implant-supported mandibular overdentures retained with ball or bar attachments: a randomized prospective 5-year study. Int J Prosthodont 2000; 13:125–130.
21. Walton JN, MacEntee MI, Glick N. One-year prosthetic outcomes with implant overdentures: a randomized clinical trial. Int J Oral Maxillofac Implants 2002; 17:391–398.