Three-Year Evaluation of Brånemark Implants Connected to Angulated Abutments

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A 3-year multicenter study on 63 maxillary and 10 mandibular fixed prostheses in 71 patients is reported. Angulated abutments or a combination of angulated and standard abutments were used to support prostheses; all components were from the Brånemark System. Of 425 implants initially placed, 4 were lost before abutment connection. Of the remaining 421 implants, 209 angulated (test) abutments and 212 standard (control) abutments were placed to support fixed prostheses. The prosthesis success rates were 96.8% for maxillae and 100% for mandibles. A total of 5.3% of the loaded test implants and 7.5% of the loaded control implants failed. The survival rates after 3 years were 91.3% for maxillary control implants, 94.8% for maxillary test implants, 97.4% for mandibular control implants, and 94.1% for mandibular test implants. The findings in this study pointed out that angulated abutments will not necessarily promote peri-implant mucosal problems. The study indicated that angulated abutments on Brånemark System implants have exhibited good preliminary results and should be comparable to the standard abutment as a predictable modality in prosthetic rehabilitation.
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Key words: angulated abutment, fixed prosthesis, osseointegrated implant, peri-implant mucosa, prosthodontic problems

Numerous studies,[1–4] both retrospective and prospective, have shown that edentulous patients treated with osseointegrated implants to support fixed prostheses can do remarkably well over time. Implants placed in the mandible tend to have a better success rate than those in the maxilla primarily because of better bone quality.[5] There is occasional need for angulated abutments to overcome compromised esthetic and functional results in situations of complicated anatomy, especially in the maxillary arch.[6–9]

Increases in abutment angulation can increase the principle strains (compressive and tensile) in the bone around the implants, as shown by in vitro strain gauge studies.[10,11] These strains have been determined to be 4 mm from the implant but could be expected to be higher at distances closer to the implant.[10,11] In an in vivo strain gauge study,[12] it was stated that a significant force was introduced in the measurement abutment when the fixed prosthesis was connected. It is unreported in the literature if this force, in combination with the abutment angulation, will introduce more clinical failures and complications compared to the standard protocol.[5]

Studies have indicated the survival rates of implants after the first year for the support of both fixed and removable prostheses.[13,14] However, none of these provides information concerning the use of angulated abutments in either the maxilla or mandible. There is also a need for clinical studies of peri-implant mucosal health around angulated[1] abutments. The purpose of the present study was to investigate the survival rate of osseointegrated implants loaded with standard or angulated abutments. Peri-implant mucosal complications in the area of the angulated abutments were also reported.[2]

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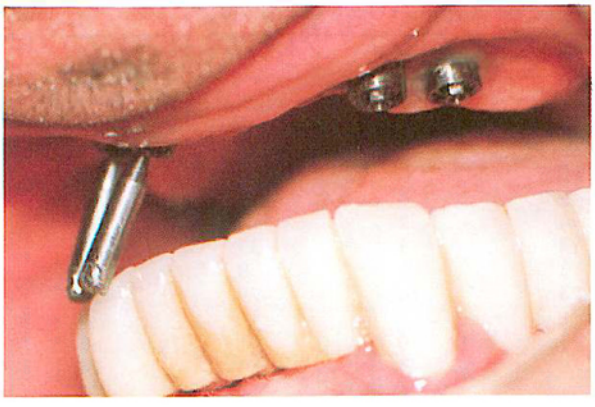

Fig 1 Two long guide pins in standard abutments show the long-axis angulation and screw access through the labial area.

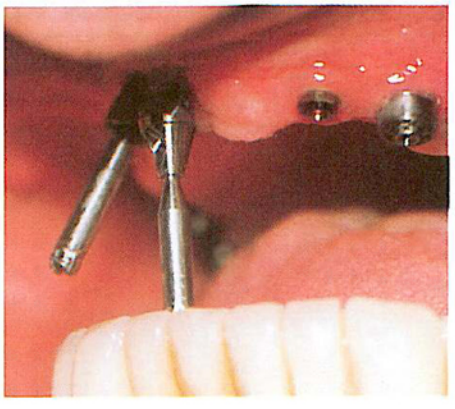

Fig 2 Changing long-axis angulation using angulated abutments permits lingual screw access for prosthesis retention.

Materials and Methods

Study Design. A 3-year multicenter study (four centers) of fixed implant-supported prostheses was designed to analyze angulated abutments on Brånemark implants (Nobel Biocare AB). Implant surgery was performed according to the standard protocol.[5] Histories were documented from the time of implant placement, abutment connection, prosthesis connection, and 1- and 2-year follow-up examinations. The patients were retrospectively included in the study, but the final 3-year examination was conducted according to a specified protocol regarding clinical assessments and radiographic evaluation.

Patients. All patients who had received Brånemark angulated abutments in the centers involved in the study before December 31, 1991, were included. Age distribution of the 71 patients at the time of implant placement ranged from 18 to 77 years, with a mean age of 54 years. The general medical history and any ongoing medication being received by the patients were recorded.

The numbers of patients who withdrew after years 1, 2, and 3 were 6, 5, and 8, respectively. During the first year after prosthesis connection, two patients lost all their implants and, consequently, their fixed prostheses. One of these patients had been treated with an autogenous bone graft, in which short implants had been placed at a later date. The other patient was a bruxer, and overload of the implants may have been a contributing factor to the failure. Because of poor compliance, 3, 4, and 4 patients were withdrawn after years 1, 2, and 3, respectively; 3 patients died and 3 patients moved from the area.

Implant Placement and Prostheses. The rationale for selecting angulated abutments was noted and recorded. In 96% of the patients, angulated abutments were used to redirect the screw access channel for implants that were unfavorably inclined (Figs 1 and 2). Other reasons were to create better parallelism and to solve proximity problems between other implants.

A total of 425 implants were placed in 71 jaws (10 mandibles and 61 maxillae) from September 7, 1988, to March 12, 1991. Table 1 indicates the number and length of standard (control) and angulated (test) implants placed. The angulated abutments used in this study had a fixed angulation of 30 degrees and were fabricated in two height ranges for the transmucosal section: *(1)* a maximum of 4 mm and a minimum of 1.5 mm; and *(2)* a maximum of 5.5 mm and a minimum of 3 mm (Fig 3).

Bone quality was determined at the time of implant placement using the Lekholm and Zarb criteria.[15] Implant losses in relation to bone quality were recorded.

For the maxilla, stage 2 surgery was performed 5 months or more after stage 1 surgery; for the mandible, it was 3 months or longer. Two maxillary implants placed in type III bone were lost before stage 2 surgery, and two mandibular implants placed in type II bone failed before loading.

A combination of standard and angulated abutments or angulated abutments only were used to support a total of 73 fixed prostheses fabricated for the 71 patients in the study (44 complete prostheses, 25 partial prostheses, 2 partial prostheses connected to implants and natural teeth, and 2 single-tooth restorations) (Fig 4).

Clinical Examination. *Survival Rate.* Implant stability was verified by applying a gentle torque to the abutments or by rocking or tapping the cylinder back and forth. Any mobility or sign of pain was recorded as a condition of nonintegration of the

Table 2 Distribution of Placed and Lost Implants

	Maxillary		Mandibular		Total	
	Placed	Lost	Placed	Lost	Placed	Lost
Control implants						
7-mm	8	1	0	0	8	1
10-mm	73	11	11	0	84	11
13-mm	39	0	6	0	45	0
15-mm	43	2	17	1	60	3
18-mm	11	1	4	0	15	1
Total	174	15	38	1	212	16
Test implants						
7-mm	2	0	1	0	3	0
10-mm	55	7	3	1	58	8
13-mm	62	0	7	0	69	0
15-mm	57	3	4	0	61	3
18-mm	16	0	2	0	18	0
Total	192	10	17	1	209	11
Total	366	25	55	2	421	27

Radiographic Examination. A radiologic examination was scheduled for measurement of the marginal bone status. However, because of the large variation in the quality of the radiographs, it was not possible to make the planned evaluation.

Statistical Analysis. Cumulative survival rates were calculated through life table analysis.[17] The chi square test was used to compare implant failures in the test and control groups.

Results

Survival Rate. Of the 212 control implants (loaded with standard abutments), 16 (7.5%) were lost. Of the 209 test implants (loaded with angulated abutments), 11 (5.3%) were lost (Table 2).

In the control group, only one of eight 7-mm implants was lost. Of the 10-mm implants placed using standard abutments, 11 of 73 were lost in the maxilla, and none of the 11 placed in the mandible was lost. Sixty 15-mm implants were placed, and 3 were lost: 2 of 43 in the maxilla and 1 of 17 in the mandible. Of the 18-mm implants placed, 1 of 11 was lost in the maxilla, and none of the 4 placed in the mandible was lost.

In the test group, none of the three 7-mm implants was lost in either the maxilla or the mandible. Eight of the 58 10-mm implants were lost: 7 in the maxilla and 1 in the mandible. The only additional implants lost were 3 of 61 15-mm implants, and all three were in the maxilla.

The total percentages of implants lost in relation to bone quality types I, II, III, and IV were 3.6%, 1.6%, 10.3%, and 0.0%, respectively. Most losses of implants were found in bone type III of the maxilla, with 11.4% from the control group and 9.8% from the test group. The number of placed and lost implants in relation to bone quality in the different groups is presented in Table 3.

The majority of failed implants (23 of 27) occurred during the first year after loading. In the maxillary control group, 12 of 174 implants failed (6.9%) during the first year after loading. Only 3 implants failed subsequently, producing a cumulative survival rate of 91.3% after 3 years. In the test group in the maxilla, 9 of 192 implants failed (4.7%) during the first year of loading and only 1 subsequently failed during the second year, for a continued survival rate of 94.8% (Table 4). In the mandible, no implants failed after the first year of loading either in the control or in the test group, and only one implant failed in each group during the first year of loading for an overall survival rate of 94.1% and 97.4% for the angulated and standard abutments, respectively (Table 4). No statistical significance was revealed when comparing test and control groups for the implant survival rate in either jaw ($P > .05$).

Prosthodontic Complications. During the first year after prosthesis connection, two patients lost all their implants in the maxilla and consequently their fixed prostheses. Only 2 of 63 fixed prostheses in the maxilla were lost, yielding a fixed prosthesis success rate of 96.8%. In the mandible, the prosthesis success rate was 100%. Other complications during the study included fracture of the occlusal material in three patients and fracture in parts of the framework in an additional three patients, one each in each year. At the follow-up examination, after 3 years, four abutment screws needed to be retightened in three patients.

Table 1 Distribution of Test and Control Abutments With Regard to Position and Length of Loaded Implants

	Maxillary		Mandibular		Total	
	Anterior	Posterior	Anterior	Posterior	Anterior	Posterior
Control implants						
7-mm	2	6	0	0	2	6
10-mm	15	58	3	8	18	66
13-mm	14	25	4	2	18	27
15-mm	19	24	14	3	33	27
18-mm	5	6	3	1	8	7
Total	55	119	24	14	79	133
Test implants						
7-mm	0	2	1	0	1	2
10-mm	34	21	0	3	34	24
13-mm	45	17	1	6	46	23
15-mm	38	19	3	1	41	20
18-mm	12	4	2	0	14	4
Total	129	63	7	10	136	73
Total	184	182	31	24	215	206

Anterior = incisor and canine regions; posterior = premolar and molar regions

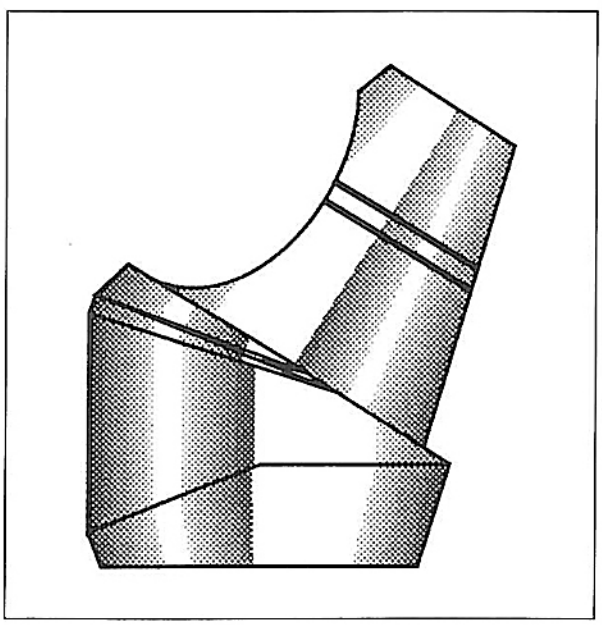

Fig 3 Angulated abutments used in this study had a fixed angulation of 30 degrees and were fabricated in two height ranges for the transmucosal section: *(1)* a maximum 4 mm and a minimum 1.5 mm; and *(2)* a maximum of 5.5 mm and a minimum of 3 mm.

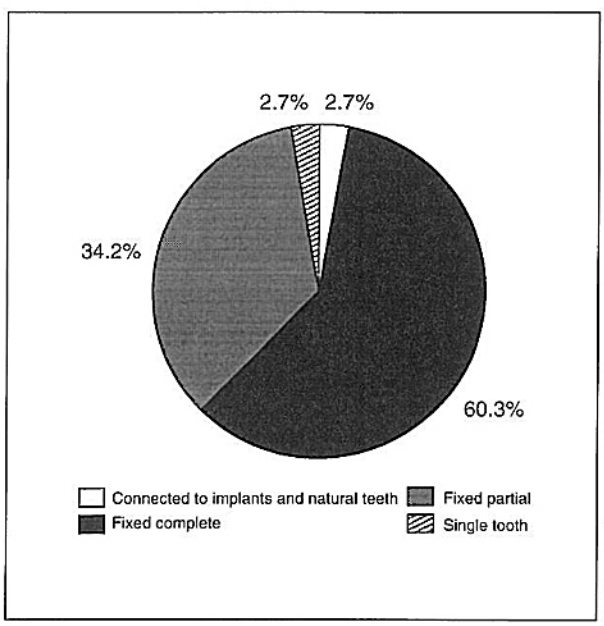

Fig 4 Types of implant-supported prostheses used.

implant.[16] Thus, the survival rate of the implant was established.

Prosthodontic Complications. Prosthodontic complications consisted of loosening of abutment screws, fracture of occlusal material, and fracture of the framework.

Peri-implant Mucosal and Gingival Health. Plaque and gingivitis were recorded for the mesiobuccal, distobuccal, mesiolingual, and distolingual surfaces of the remaining natural teeth and of the abutments in both jaws. Plaque was recorded according to the Sillness and Löe Index, and gingivitis was recorded according to the Löe and Sillness Index. Pocket depth was recorded to the nearest millimeter on the aforementioned surfaces. Only depths above 3 mm were recorded.

situated subgingivally, which may produce a hygiene maintenance problem. In these situations, surgical correction of the mucosal level might be indicated. However, in the present study, the number of patients with reported gingival problems in the peri-implant area around the angulated abutment did not seem to differ from those patients with general gingival problems in the peri-implant area of standard abutments or gingival problems around remaining natural teeth. A reasonable explanation for this could be that most of the angulated abutments were placed supragingivally.

Sometimes the use of angulated abutments solves one esthetic problem, ie, a buccally inclined implant, but creates another, as when the implant is superficially placed, thus making the abutment shoulder too high. The so-called *knee* of the angulated abutment (see Fig 3) may be visible and can produce an esthetic problem, especially in patients with a high lip line. In 1995, Nobel Biocare introduced an abutment with a fixed angulation of 17 degrees and a much shorter shoulder. This angulated abutment will probably be useful in the aforementioned clinical situation. However, the ability to use angulated abutments should not compensate for inadequate treatment planning.

The prosthodontic complications recorded during follow-up examinations were few, and the three recorded framework fractures could be repaired. However, during the first year of function, two patients lost their maxillary fixed prostheses. The prosthesis success was 96.8% and 100% for the maxillary and mandibular restorations, respectively. This is comparable to other long-term results.[19]

The majority of implants treated with both standard and/or angulated abutments were placed in type III bone (see Table 3). Approximately 10% of these implants were lost, both in the control group and in the test group. Comprehensively, a total number of 27 implants were placed in bone with a quality that was estimated as type IV, but none of these implants was lost. It should also be noted that none of the 7-mm implants connected to angulated abutments was lost during the follow-up period.

In vitro strain gauge studies[10,11] have indicated that compressive and tensile strains increase in the bone around implants with angulated abutments. Moment and torque forces on the implants have also been discussed.[20,21] These studies could indicate a lower survival rate of implants connected to angulated abutments. However, in the present study, the cumulative survival rates are similar in the test and control groups, both in the maxilla and in the mandible. There was a somewhat better survival rate for the maxillary test implants, compared to the maxillary control implants. This may be related to the fact that the angulated abutments were more frequently used in the anterior maxilla, and the standard abutments were more frequently used in the posterior maxilla. There are often higher occlusal forces in the posterior region, as well as a reduced bone quality. These factors have been shown to play an important role in the survival of implants placed in the posterior region of the maxilla and the mandible.

There has also been an experimental study in subhuman primates, including histologic evaluation, showing that after 1 year of service, the implants exhibited complete osseointegration, whether restored with straight or angled abutments.[22] The effect of clinical experience on success of implant treatment has been shown.[23] A variation in results could also be the result of variation in clinical experience among the four centers participating. Furthermore, subjective reporting of details, such as bone quality, can differ from one center to the next.

Soft tissue problems, including peri-implant mucosal problems, are most often related to plaque accumulation, and they are frequently resolved by improved oral hygiene.[24] No differences concerning the number of patients with problems in gingiva in general and in peri-implant mucosal tissues of the angulated abutment could be seen from year to year. This indicated that angulated abutments will not, of themselves, promote peri-implant mucosal problems. The same indication was obtained in a 1-year study of subhuman primates.[22]

Nine of the patients (13%) in the present study needed additional prosthodontic treatment. The need for this treatment was the result of loose abutment screws (3), fracture of occlusal material (3), and framework fracture (3). In a study of 600 osseointegrated implant-supported fixed and removable prostheses examined by Carlson and Carlsson,[25] 28% needed some prosthodontic treatment. Fracture of the metal framework and acrylic resin portion of fixed implant-supported prostheses has been reviewed.[24] This review[24] showed wide variation in the incidence of fracture (0.5% to 46.0%) of metal frameworks and 14% (maxillae) to 1.7% (mandibles) of the acrylic resin portion. Thus, there was minimal need for treatment because of prosthodontic complications in the present study in both test and control groups.

Conclusion

The prosthesis success rate was 96.8% for maxillary restorations and 100% for mandibular restorations. For the maxilla, a 91.3% implant survival rate for the control group was compared to the 94.8% implant survival rate for the test group. For the mandible, the control group demonstrated a 97.4% implant survival

Table 3 Number of Implant Failures Related to Bone Quality

	Bone quality				
	I	II	III	IV	Not recorded
Control					
Maxillary					
Placed	6	25	123	17	3
Lost	0	1	14	0	0
Mandibular					
Placed	12	20	6	0	0
Lost	1	0	0	0	0
Test					
Maxillary					
Placed	8	67	102	10	5
Lost	0	0	10	0	0
Mandibular					
Placed	2	12	3	0	0
Lost	0	1	0	0	0
Total					
Placed	28	124	234	27	8
Lost	1	2	24	0	0

Table 4 Cumulative Survival Rates of Maxillary and Mandibular Implants

	Control implants				Test implants			
Time period	n	Lost	Withdrawn	CSR (%)	n	Lost	Withdrawn	CSR (%)
Maxillary								
Abutment to 1 y	174	12	3	93.1	192	9	10	95.3
1 to 2 y	159	1	8	92.5	173	1	9	94.8
2 to 3 y	150	2	23	91.3	163	0	29	94.8
3 y	125				134			
Mandibular								
Abutment to 1 y	38	1	7	97.1	17	1	1	94.1
1 to 2 y	30	0	4	97.4	15	0	1	94.1
2 to 3 y	26	0	0	97.4	14	0	0	94.1
3 y	26				14			

Peri-implant Mucosal and Gingival Health. Gingival problems in the areas around the angulated abutments were observed in nine patients (14%) at the 1-year follow-up examination, in five patients (8%) at the 2-year follow-up examination, and in seven patients (13%) at the 3-year follow-up examination. These figures were comparable to or lower than those observed in the peri-implant area of standard abutments or around remaining natural teeth.

Discussion

In most clinical situations, it may be possible to place an implant within the bone so that the implant angulation matches that of the desired prosthodontic restoration. However, in atrophic maxillae, it may not be possible to vary implant angulation without additional grafting procedures because of the narrow alveolar ridge. In those instances, the implant will likely be placed in an undesirable position with respect to both inclination and location. It has been reported that even one-stage procedures involving implant placement in combination with bone grafting in the maxilla can also result in unfavorable inclination of the implants.[18] To overcome the esthetic shortcomings in these situations, there is a need for the use of angulated abutments. In 96% of the patients participating in this study, angulated abutments were used to redirect the access channel. Although two single-tooth restorations were also included in this study, the angulated abutment is not designed for this purpose because there is no rotational interlock between the gold cylinder and the abutment.

The angulated abutments were available with two shoulder heights for the treatment of different clinical situations covering variations in mucosal thickness. If the shoulder is too low, the abutment will be

rate, and the test group had an implant survival rate of 94.1%. Thirteen percent of the patients needed additional prosthodontic treatment (loose abutment screws, fracture of occlusal material, and framework fracture).

No differences concerning the number of clinical situations with gingival problems in general and with peri-implant mucosal tissues around the angulated abutment, compared to around the standard abutment, could be seen from year to year. In this study, this indicated that the angulated abutment will not necessarily promote peri-implant mucosal problems. The study indicated that angulated abutments of Brånemark implants have exhibited good preliminary results and may be considered comparable to the standard abutment as a predictable modality in prosthetic rehabilitation.

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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. 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 prosthesis design: A prospective study on 1273 fixtures. J Head Neck Pathol 1991;10:43–53.
3. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: The Toronto study. Part I: Surgical results. J Prosthet Dent 1990;63:451–457.
4. Balshi TJ, Lee HY, Hernandez R. The use of pterygomaxillary implants in the partially edentulous patient: A preliminary report. Int J Oral Maxillofac Implants 1995;10:89–98.
5. Brånemark P-I, Zarb GA, Albrektsson T. Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985.
6. Kallus T, Henry P, Jemt T, Jörnéus L. Clinical evaluation of angulated abutments for the Brånemark system: A pilot study. Int J Oral Maxillofac Implants 1990;5:39–45.
7. ten Bruggenkate CM, Sutter F, Oosterbeek HS, Schroeder A. Indications for angled implants. J Prosthet Dent 1992;67: 85–93.
8. ten Bruggenkate CM, Oosterbeek HS, Krekeler G, Asikainen PJ. The placement of angled implants in the edentulous maxillae for the use of overdentures. J Prosthet Dent 1991;66: 807–809.
9. Geld DA, Lazzara RJ. Hierarchy of objectives in implant placement to maximize esthetics: Use of pre-angulated abutments. Int J Periodont Rest Dent 1993;13:277–287.
10. Clelland NL, Gilat A, McGlumphy EA, Brantley WA. A photoelastic and strain gauge analysis of angled abutments for an implant system. Int J Oral Maxillofac Implants 1993;8: 541–548.
11. Clelland NL, Gilat A. The effect of abutment angulation on stress transfer for an implant. J Prosthodont 1992;1:24–28.
12. Jemt T, Carlsson L, Boss A, Jörnéus L. In vivo load measurements on osseointegrated implants supporting fixed or removable prostheses: A comparative pilot study. Int J Oral Maxillofac Implants 1991;6:413–417.
13. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: A study of treatment from the time of prosthesis placement to the first annual check-up. Int J Oral Maxillofac Implants 1991;6:270–276.
14. 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 check-up. Int J Oral Maxillofac Implants 1992;7:162–167.
15. 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, 1985:199–220.
16. Albrektsson T, Zarb G. Current interpretations of the osseointegrated response: Clinical significance. Int J Prosthodont 1993;6:95–105.
17. Pocock SJ. Clinical Trials. A Practical Approach. New York: Wiley, 1983:221–224.
18. Isaksson S, Ekfeldt A, Alberius P, Blomqvist JE. Early results from reconstruction of severely atrophic (Class VI) maxillas by immediate endosseous implants in conjunction with bone grafting and Le Fort I osteotomy. Int J Oral Maxillofac Surg 1993;22:144–148.
19. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
20. Rangert B, Jemt T, Jörnéus L. Forces and moments on Brånemark implants. Int J Oral Maxillofac Implants 1989;4: 241–247.
21. Weinberg LA, Kruger B. A comparison of implant/prosthesis loading with four clinical variables. Int J Prosthodont 1995;8:421–433.
22. Celletti R, Panneijer CH, Bracchetti G, Donath K, Persichetti G, Visani I. Histologic evaluation of osseointegrated implants restored in nonaxial functional occlusion with preangled abutments. Int J Periodont Rest Dent 1995;15:563–573.
23. Preiskel HW, Tsolka P. Treatment outcomes in implant therapy: The influence of surgical and prosthodontic experience. Int J Prosthodont 1995;8:273–279.
24. Schakleton JL, Carr L. Brånemark fixed implant-supported prostheses: A review of prosthetic problems. J Dent Assoc South Afr 1995;49:293–298.
25. Carlson B, Carlsson GE. Prosthodontic complications in osseointegrated dental implant treatment. Int J Oral Maxillofac Implants 1994;9:90–94.