＜臨床研究＞

Clinical Investigation of Hydroxyapatite-Coated Dental Implants (SUMICIKON®)

—— Long-term Evaluation of Occlusal Force and Peri-implant Gingiva ——

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Hydroxyapatite-Coated Dental Implant の臨床的検討

—— 咬合力およびインプラント体周囲歯肉の長期的評価 ——

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HAP implants bond directly with bone, the load and distribution of occlusal force differs from that of natural teeth, which have physiological motility. More specifically, we considered the occlusal force is a key measure of the restoration of chewing ability. We performed a clinical investigation of the restoration of chewing ability and changes over time in peripheral gingiva in patients that had received HAP-coated dental implants (SUMICIKON®)

The results and implications can be summarized as follows：

1) After implantation the occlusal force tends to rise on both the implants side and the non-implant side after the first year, and adaptation to the implant contributes to the restoration of chewing ability from the standpoint of occlusal force.

2) Restoration of chewing ability was good (39/40 patients), fair (1/40 patients) and poor (0/40 patients), indicating that restoration of chewing ability, including QOL, was achieved.

3) No obvious inflammation was observed in the peri-implant gingiva surrounding after 6 months, and the gingiva remained stable.

Key words：*HAP-coated dental implants, occlusal force, chewing ability, peri-implant gingiva*

Introduction

The diminished chewing ability, pronunciation difficulties and loss of esthetics that accompany tooth loss have traditionally been restored by removable dentures or fixed dental prostheses, but in recent years the use of dental implants has become lege artis. The nature of the bone-to-implant interface has been extensively investigated, and the success of a dental implant is believed to depend on the selection of a suitable implant mate-

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rial, the establishment of good surgical procedure, and the recognition of the importance of postoperative maintenance.

Implants made of various types of materials have been developed and used clinically.

At present, implants made of hydroxyapatite (HAP) and titanium are primarily used HAP is considered to be an excellent implant material because it has the same type of structure as biological hard tissue, and has good biocompatibility and bone conduction. Because HAP implants bond directly with bone[1,2], the load and distribution of occlusal force differs from that of natural teeth, which have physiological motility. More specifically, we considered the occlusal force is a key measure of the restoration of chewing ability.

We report here a clinical investigation of the restoration of chewing ability in patients with HAP-coated dental implants and changes over time in the peri-implant gingiva.

Subjects and Methods

1. Subjects

The subjects consisted of 40 patients who received HAP-coated dental implants (SUMICIKON®), during the period between 1985 and 1992, at the Department of Oral and Maxillofacial Surgery I, Matsumoto Dental University, Japan. All subjects satisfied the following conditions : (1) at least 5 years had passed since implantation, (2) implantation was in the molar region, (3) the patient did not have a non-fixed prosthesis on the non-implant side of the mouth, (4) there was no pain of the mandibular joint or muscles involved in chewing and no impairment of jaw movement, and (5) the patient responded to all recalls for maintenance (Table 1). The subjects comprised 19 males and 21 females,

Table 1 Data of Patients Included in the Study

Case	Sex	Age	Ope. Date	Standard	Implant Site	Case	Sex	Age	Ope. Date	Standard	Implant Site
1	M	32	1985.05.17	SUS-20-D	⌈6 7	21	M	43	1986.12.09	STS-15-D	7⌋
2	F	46	1985.08.02	SUS-23-D	7 6 5 4⌋	22	M	38	1986.12.09	SUS-20-D	6 5⌋
3	F	32	1985.08.02	SUS-23-D	7 6 5⌋	23	F	58	1986.12.25	STS-15-D	7 6⌋
4	M	60	1985.08.06	SUS-20-D	⌈6 7	24	M	49	1987.01.13	SUS-20-D	⌈5 6 7
5	F	32	1985.09.20	SUS-23-D	⌈5 6 7	25	F	58	1987.01.16	SUS-20-D	⌈5 6 7
6	F	48	1985.10.04	STS-15-D	7 6⌋	26	M	38	1987.02.03	SUS-20-M 1	⌈6 7
7	F	62	1985.10.04	STS-15-D	7 6⌋	27	F	34	1987.03.10	SUS-23-D	⌈4 5 6
8	F	73	1985.11.13	STS-15-D	⌈5 6	28	F	46	1987.07.10	SUS-23-M 1	⌈6 7
9	F	55	1986.01.28	STS-15-D	⌈6 7	29	M	63	1988.09.20	SUL-23-D	6 5 4⌋
10	M	32	1986.03.31	SUS-20-D	⌈5 6 7	30	M	43	1989.01.20	STS-15-D	⌊6
11	M	60	1986.04.08	STS-15-D	6 5⌋	31	F	50	1989.04.17	SUS-23-M 1	⌈4 5 6
12	F	51	1986.06.02	STS-15-D	⌈6 7	32	M	45	1990.02.27	STS-15-D	6⌋
13	F	39	1986.06.16	STS-15-D	⌈6 7	33	M	41	1990.10.23	STS-15-M 1	⌈7
14	M	53	1986.07.18	STS-15-D	⌈6 7	34	F	44	1991.01.22	SUS-20-M 1	7 6⌋
15	F	59	1986.08.27	STS-15-D	7 6⌋	35	F	50	1991.05.21	STS-20-M 1	7⌋
16	M	43	1986.09.18	SUS-15-D	⌈6 7	36	M	62	1991.09.02	STS-15-M 1	7⌋
17	F	54	1986.06.25	SUS-23-D	7 6 5⌋	37	M	39	1991.12.11	STS-20-M 1	⌈7
18	F	33	1986.10.06	STS-15-D	6 5⌋	38	M	43	1992.02.05	SUS-23-M 1	7 6 5⌋
19	F	58	1986.10.13	SUS-20-D	⌊5 6 7	39	M	62	1992.02.26	SUS-20-M 1	⌈5 6 7
20	F	58	1986.10.27	STS-15-D	5 4⌋	40	M	49	1992.03.19	SUS-20-M 1	⌈6 7

and the average age was 48 years, with 10 patients ages 30-39, 12 aged 40-49, 11 aged 50-59, 6 aged 60-69 and 1 aged 70-79. There were 6 cases with maxillary implants and 34 cases with mandibular implants. According to Kennedy cllasification, 4 cases were class 3-A and 36 cases were class 2-A. The plate types used were as follows : a 15 mm single head in 16 cases, a 15 mm double head in 2 cases, a 20 mm single head in 2 cases, a 20 mm double head in 11 cases, and a 23 mm double head in 9 cases. The longest observation period among the subjects was 12 years.

2. Methods

Implantation were according to standard procedures. After mucoperiosteal reflection, the channel was prepared and is depth tested with titanium gaige, the angle of the abutment head adjusted, and the implant lightly tapped into place with the shoulder sitting 2-3 mm below the crest of the alveolar ridge.

Examinations were performed at 3 months, 6 months, and 1 year after implantation and every year thereafter. Occlusal force was measured using an MPM-3000 (Nihon Koden Kogyo). The subject seated uplight position and measurement was performed 3 times on the area corresponding to the implant head to obtain the mean bite force, a 5-10 min interval was provided between each measurement. Occlusal force on the non-implant side was measured 3 times in the same manner, and the mean bite force value was used as a control. In addition, a surve was conducted based on the Chewing Evaluation Chart developed by Yamamoto[3]. This survey provides an evaluation of chewing ability and the time required for restoration of chewing ability as perceived by the patient.

Evaluation of peri-implant gingival condition was performed using Periotoron units, gingival index, and probing depth. For the Periotoron units (HARCO ELECTRONICS LTD, Canada), the maximum value from the 4 surfaces was used, and for double-headed implants both the proximal and distal heads were measured and the maximum value used. The measurement were performed as follows : under the simmple exclusion of moisture GCFM was put into the sulcus, after three seconds the GCFM was removed. And then the GCFM was set on and measured by the Periotoron units (HARCO ELECTRONICS LTD, Canada).

For the gingival index, the peri-implant gingiva was divided into 4 areas (buccal, lingual, mesial and distal side of the implant head) and each was given a score as usual manner[4]. The probing depth was assessed by measuring both the proximal and distal sides of the head, and for double headed implants, both the proximal and distal heads were measured and the maximum value used.

3. Evaluation Criteria

The following items were evaluated in the clinical cases.

1) Change in occlusal force due to implantation

2) Evaluation of chewing ability according to Chewing Evaluation Chart

3) Evaluation of the condition of peri-implant gingiva by gingival index, Periotoron units and probing depth.

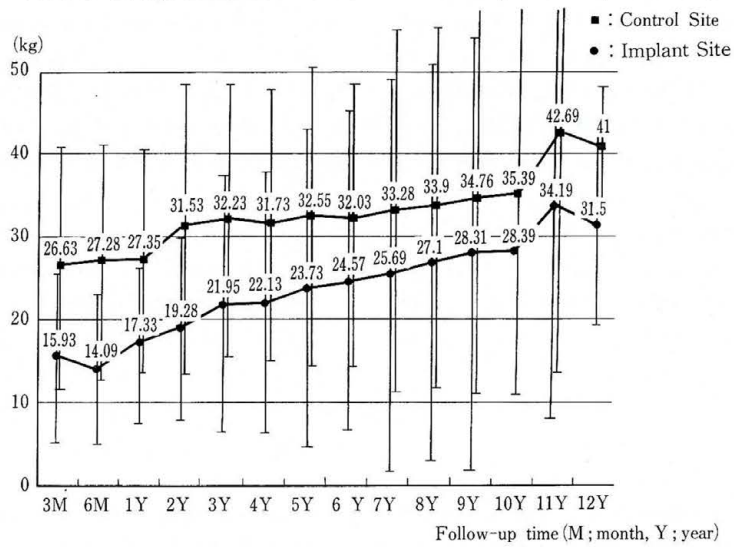
Results

1. Change in Occlusal Force Due to Implantation

The mean occlusal force 3 months after implantation was 15.93 kg on the implant side and 26.63 kg on the non-implant side. After 5 years, the mean occlusal force was 23.73 kg on the implant side and 32.55 kg on the non-implant side. In the large majority of cases the occlusal force increased after 1 year post-implantation, and the occlusal force tended to increase on the non-implant side as the occlusal force on the implant side increased (Table 2).

A comparison between occlusal force at 3 months post-implantation and at the final measurement revealed that in 2 cases occlusal force had decreased on the implant side, in 2 cases there was no change, and in 36 cases occlusal force had increased. On

Table 2 Change in mean occlusal force after the implantation (mean±S.D).



the non-implant side the occlusal force had decreased in 5 cases, had not changed in 1 cases, and had increased in 34 cases (Table 3).

2. Evaluation of Chewing Ability using the Chewing Evaluation Chart

Chewing ability, as evaluated by the Yamamoto Chewing Evaluation Chart[3] was good in 39 cases, fair in 1 cases, and poor on 0 cases. At present, 39 of 40 patients report that they can chew as well as they did with their natural teeth. Of 39 patients, 22 reported being able to chew as well as with their own teeth immediately after installation of the prosthetic restoration, 14 within 3 months, 2 within 6 months, and 1 within 1 year.

3. Evaluation of Condition of Peri-Implant Gingiva by gingival Index, Periotoron Units and Probing Depth (Table 4~6)

With respect to the condition of the peri-implant gingiva as measured by Periotoron units and gingival index, mild inflammation was identified up to 3 months after implantation in 2 patients and up to 6 months after implantation in 1 patient. However, subsequent examinations revealed no inflammation in these patients, and the peri-implant gingiva remained stable.

Discussion

Although removable dentures or fixed dental prostheses have traditionally been used to restore the diminished chewing ability, pronunciation difficulties, and loss esthetics that accompany tooth loss, in recent years the use of dental implants has become the method of choice. Osborn et al have classified materials into 3 categories based on the material-to-bone interface : bio-tolerant, bio-inert, and bioactive[5], HAP is a bioactive material. Ogiso has described the utility of HAP as an implant material, stating that it bonds chemically to bone without involvement of the soft tissues[6,7]. Although there have been some clinical studies of the various types of implants utilizing HAP as a base material[8-10], the present study is the first to observe and report the long-term effects of such implants.

The primary objective of implantation therapy is to restore the loss of chewing ability, pronunciation difficulties, and loss of esthetics caused by tooth loss. However, an understanding of implant dynamics is essential for long-term success. In the

Table 3-1 Change in occlusal force due to implantation

No. \ Time	3 M	6 M	1 Y	2 Y	3 Y	4 Y	5 Y	6 Y	7 Y	8 Y	9 Y	10 Y	11 Y	12 Y
1 (C)	30	30	30	28	30	28	30	34	36	37	39	39	50	49
1 (I)	18	17	17	17	19	27	30	34	36	38	39	39	49	49
2 (C)	24	24	24	31	32	33	34	35	32	32	31	35	35	34
2 (I)	18	18	16	15	14	18	14	17	18	18	19	18	19	19
3 (I)	20	19	19	25	32	32	33	32	31	33	32	33	33	34
3 (C)	37	37	37	35	39	39	39	38	39	40	39	40	40	40
4 (C)	38	39	39	38	37	37	39	38	40	40	39	41	40	41
4 (I)	27	26	26	23	24	23	20	23	24	23	23	23	24	24
5 (C)	29	28	29	31	31	30	32	31	33	31	32	33	32	
5 (I)	16	15	17	16	18	18	19	18	21	22	23	23	23	
6 (C)	19	19	19	41	43	42	41	47	44	46	47	45	46	
6 (I)	11	11	11	20	21	21	23	25	24	25	23	24	24	
7 (I)	9	9	9	13	28	29	28	33	31	28	30	31	30	
7 (C)	13	13	13	22	31	39	29	25	27	27	28	28	28	
8 (C)	37	37	37	37	37	37	36	35	27	28	13	13	14	
8 (I)	14	14	14	17	17	18	18	19	17	24	19	18	19	
9 (C)	12	12	12	12	14	14	14	13	13	14	14	15	14	
9 (I)	12	12	12	12	13	13	13	14	14	14	14	14	13	
10 (C)	89	89	89	122	116	113	128	125	147	138	155	152	163	
10 (I)	64	64	64	73	106	107	136	136	147	149	157	151	135	
11 (C)	10	10	10	16	18	16	19	19	18	18	18	19	19	
11 (I)	7	7	7	8	9	8	10	11	10	10	11	10	11	
12 (C)	14	13	19	19	28	37	35	34	32	36	38	37	36	
12 (I)	19	19	23	43	44	47	46	50	51	51	50	50	51	
13 (C)	41	40	48	61	62	60	65	58	57	55	56	58	57	
13 (I)	28	27	25	32	51	49	51	51	50	52	51	50	55	
14 (C)	41	41	42	41	39	41	45	39	40	39	40	41	41	
14 (I)	44	44	42	39	42	42	41	40	41	42	44	42	43	
15 (C)	5	5	15	14	15	15	16	15	17	17	19	19	21	
15 (I)	4	7	7	9	10	9	10	10	11	11	12	12	13	
16 (C)	28	27	27	29	28	27	29	30	29	29	30	31	30	
16 (I)	16	15	15	17	18	17	20	19	21	21	20	22	22	
17 (C)	9	9	9	17	19	17	17	19	19	20	19	20		
17 (I)	7	7	10	10	14	14	14	14	15	15	15	14		
18 (C)	19	34	34	34	36	37	36	38	38	48	45	56		
18 (I)	6	11	14	18	17	19	22	34	29	36	33	34		
19 (C)	6	13	23	30	33	12	16	17	20	19	20	21		
19 (I)	10	15	17	22	20	12	19	18	19	17	19	19		
20 (C)	15	14	16	18	21	20	22	20	21	23	24	24		
20 (I)	15	15	16	21	21	22	22	24	23	25	25	25		

C : Control Site I : Implant Site
Follow-up time (M ; month, Y ; year)

Table 3-2 Change in occlusal force due to implantation

No. \ Time	3 M	6 M	1 Y	2 Y	3 Y	4 Y	5 Y	6 Y	7 Y	8 Y	9 Y	10 Y	11 Y	12 Y
21 (C)	16	15	16	17	16	18	17	18	17	19	18	18		
21 (I)	23	22	23	24	23	21	21	20	21	23	22	22		
22 (C)	13	13	12	14	13	15	14	15	15	16	14	15		
22 (I)	23	22	24	23	23	24	23	24	24	22	23	24		
23 (C)	12	16	16	24	23	24	24	25	26	27	28	28		
23 (I)	6	21	21	24	23	24	27	26	25	26	26	27		
24 (C)	31	31	32	31	33	32	31	33	33	35	32	32		
24 (I)	16	16	15	18	20	20	21	23	22	21	22	24		
25 (C)	18	21	22	21	22	23	22	24	25	25	24	25		
25 (I)	15	15	17	19	19	18	20	19	20	20	20	19		
26 (C)	29	30	31	29	30	29	29	31	32	30	33	32		
26 (I)	18	17	17	18	19	20	20	22	21	21	23	21		
27 (C)	21	22	21	24	25	24	26	25	26	25	26	25		
27 (I)	12	12	14	15	15	17	18	18	19	18	19	19		
28 (C)	21	20	22	21	22	20	23	22	23	20	21	24		
28 (I)	11	10	12	12	12	13	12	13	12	12	13	12		
29 (I)	13	12	15	19	19	19	21	20	19	22	21			
29 (C)	47	49	16	51	51	38	38	36	38	40	39			
30 (C)	19	21	21	20	20	21	19	21	20	23				
30 (I)	9	9	10	9	12	11	13	13	12	14				
31 (C)	25	25	26	25	28	26	25	25	25	27				
31 (I)	12	12	13	12	13	13	15	15	13	14				
32 (I)	11	11	12	11	11	12	13	15	14					
32 (C)	24	23	23	22	24	23	22	24	23					
33 (C)	32	33	32	34	33	32	33	31						
33 (I)	14	13	13	14	15	14	16	14						
34 (I)	15	14	16	15	15	15	17	15						
34 (C)	21	20	23	22	22	24	24	23						
35 (C)	11	11	12	14	13	13	14	15						
35 (I)	20	19	21	20	20	21	23	24						
36 (C)	18	17	18	21	21	23	23							
36 (I)	31	30	30	31	30	34	33							
37 (C)	38	37	39	38	40	39	41							
37 (I)	19	18	18	21	23	22	24							
38 (I)	21	20	22	24	23	24	25							
38 (C)	35	36	35	38	36	37	38							
39 (C)	29	31	28	31	32	31	32							
39 (I)	15	14	16	18	17	18	18							
40 (C)	38	37	39	39	40	39	40							
40 (I)	19	18	21	23	25	24	25							

C : Control Site I : Implant Site
Follow-up time (M ; month, Y ; year)

Table 4 Change in Gingival Index due to implantation

No. \ Time	3 M	6 M	1 Y	2 Y	3 Y	4 Y	5 Y	6 Y	7 Y	8 Y	9 Y	10 Y	11 Y	12 Y
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	0	0	0	0	0	0	
7	0	0	0	0	0	0	0	0	0	0	0	0	0	
8	0	0	0	0	0	0	0	0	0	0	0	0	0	
9	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	0	0	0	0	0	0	
11	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	0	0	0	0	0	0	0	0	0	0	0	0	0	
13	0	0	0	0	0	0	0	0	0	0	0	0	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	
15	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	0	0	0	0	
17	1	1	0	0	0	0	0	0	0	0	0	0		
18	0	0	0	0	0	0	0	0	0	0	0	0		
19	0	0	0	0	0	0	0	0	0	0	0	0		
20	0	0	0	0	0	0	0	0	0	0	0	0		
21	0	0	0	0	0	0	0	0	0	0	0	0		
22	0	0	0	0	0	0	0	0	0	0	0	0		
23	0	0	0	0	0	0	0	0	0	0	0	0		
24	1	1	0	0	0	0	0	0	0	0	0	0		
25	0	0	0	0	0	0	0	0	0	0	0	0		
26	0	0	0	0	0	0	0	0	0	0	0	0		
27	0	0	0	0	0	0	0	0	0	0	0	0		
28	0	0	0	0	0	0	0	0	0	0	0	0		
29	0	0	0	0	0	0	0	0	0	0	0			
30	0	0	0	0	0	0	0	0	0	0				
31	1	0	0	0	0	0	0	0	0	0				
32	0	0	0	0	0	0	0	0	0					
33	0	0	0	0	0	0	0	0						
34	0	0	0	0	0	0	0	0						
35	1	1	0	0	0	0	0	0						
36	0	0	0	0	0	0	0							
37	0	0	0	0	0	0	0							
38	0	0	0	0	0	0	0							
39	0	0	0	0	0	0	0							
40	0	0	0	0	0	0	0							

Follow-up time (M ; month, Y ; year)

Table 5-1 Change in Periotoron Unit due to implantation

No. \ Time	3M	6M	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	11Y	12Y
1 (M)	3	2	2	0	0	0	1	1	1	1	1	1	1	1
1 (D)	3	1	1	0	1	0	0	0	0	0	0	0	0	0
2 (M)	2	2	2	1	1	1	1	1	1	1	0	0	1	1
2 (D)	3	2	2	2	2	2	1	1	0	0	0	0	0	0
3 (M)	3	3	2	1	1	1	1	0	0	0	0	0	0	0
3 (D)	3	2	1	0	0	0	0	0	0	0	0	0	0	0
4 (M)	4	4	2	2	2	2	2	2	2	3	4	1	3	1
4 (D)	3	3	2	2	2	2	2	2	3	2	2	1	2	2
5 (M)	2	2	2	2	2	2	2	2	2	2	3	2	3	
5 (D)	3	3	3	2	2	2	3	3	2	2	2	2	2	
6	2	2	2	2	2	3	3	3	4	3	3	3	3	
7	5	5	4	4	3	3	3	2	2	3	3	3	2	
8	3	3	3	3	2	2	2	1	0	1	1	1	1	
9	2	3	2	2	2	3	1	1	1	1	1	1	1	
10 (M)	4	1	2	0	0	0	1	1	1	3	1	2	1	
10 (D)	4	2	2	1	0	0	0	1	1	1	1	1	1	
11	3	2	2	2	2	2	2	1	1	1	1	1	1	
12	2	0	2	1	1	0	1	1	1	1	1	1	1	
13	3	2	2	0	0	1	1	0	0	0	0	1	1	
14	3	0	1	1	0	2	2	1	2	1	0	0	0	
15	2	2	2	2	2	1	1	1	2	2	1	1	0	
16 (M)	4	5	4	4	2	3	1	1	1	0	0	1	1	
16 (D)	5	5	4	3	3	1	1	0	1	1	1	1	1	
17 (M)	6	6	4	4	4	3	3	2	1	0	0	0		
17 (D)	7	6	3	3	2	2	3	2	1	1	1	1		
18	3	3	1	2	0	0	2	2	0	1	1	1		
19 (M)	3	1	1	1	1	1	1	1	1	1	1	1		
19 (D)	3	1	1	1	1	1	1	1	1	1	1	1		
20	2	3	1	1	1	1	1	1	1	1	1	1		
21	4	2	2	3	1	1	1	1	1	1	1	1		

(M) : Medical Site of the Implant (D) : Distal Site of the Implant
Follow-up time (M ; month, Y ; year)

case of tooth loss, regardless of the type of therapy selected, including implantation, an evaluation of chewing ability is very important as an index for judging therapeutic efficacy. Many methods for objectively evaluating chewing ability have been investigated, and these include measurements of occlusal force[11-13], chewing efficiency[14], muscle activity during chewing, and lower jaw movement[15].

Among these, the measurement of occlusal force is the most effective for evaluating chewing ability as occlusal force is mediated by 3 factors : the contractile force of the groups of chewing muscles and muscles that close the mouth, the resistance of the mucosa and bone, and the function of the mandibular joints as a fulcrum. We evaluated chewing ability by measuring occlusal force. Moreover, although it is necessary to both establish evaluation

Table 5-2 Change in Periotoron Unit due to implantation

No. \ Time	3 M	6 M	1 Y	2 Y	3 Y	4 Y	5 Y	6 Y	7 Y	8 Y	9 Y	10 Y	11 Y	12 Y
22 (M)	2	2	2	1	1	1	0	0	1	0	0	1		
22 (D)	2	2	2	2	1	0	0	0	0	1	0	0		
23	2	3	4	5	2	0	1	1	0	0	0	0		
24 (M)	8	5	5	3	3	3	2	1	2	2	1	1		
24 (D)	7	5	5	2	2	2	1	1	2	2	2	2		
25 (M)	5	2	2	2	3	2	1	2	2	2	2	2		
25 (D)	3	2	2	1	2	1	1	1	0	0	0	1		
26 (M)	6	6	5	3	5	3	3	3	1	1	1	1		
26 (D)	5	6	3	3	4	3	2	1	1	0	1	1		
27 (M)	3	2	0	0	0	1	0	0	0	1	1	1		
27 (D)	2	1	0	0	0	0	0	0	0	0	1	1		
28 (M)	3	2	2	2	2	1	1	1	1	1	1	1		
28 (D)	3	3	2	2	2	1	1	1	1	1	1	1		
29 (M)	4	4	3	3	3	2	2	2	3	3	2			
29 (D)	2	2	3	3	2	2	2	2	1	1	1			
30	3	3	2	2	1	2	1	1	0	0				
31 (M)	6	5	6	5	3	3	5	3	3	2				
31 (D)	6	6	5	3	4	4	3	3	3	3				
32	4	4	4	2	2	3	3	2	3					
33	2	1	1	1	0	0	1	1						
34 (M)	4	3	2	1	1	1	1	1						
34 (D)	2	2	2	1	0	0	0	0						
35	7	7	5	3	3	3	2	1						
36	2	2	2	1	1	1	1							
37	4	4	2	2	0	0	0							
38 (M)	3	2	2	1	1	0	0							
38 (D)	3	2	2	1	1	1	1							
39 (M)	5	2	5	1	0	0	1							
39 (D)	4	2	2	1	1	1	0							
40 (M)	2	1	0	0	0	0	0							
40 (D)	2	1	0	1	0	0	1							

(M) : Medical Site of the Implant (D) : Distal Site of the Implant
Follow-up time (M ; month, Y ; year)

criteria and objectively analyze the evaluation results, chewing ability can be simply investigated by conduction a questionnaire of foods that can be eaten following implantation. Because this is effective as an overall indicator of chewing ability, we also evaluated chewing ability Yamamoto's Chewing Evaluation Chart[3].

At 3 months post-implantation, the mean bite force on the implant side was 15.93 kg compared with 26.63 kg for the non-implant side, and thus the occlusal force on the implant side was lower than that of healthy natural permanent teeth. We believe that this was because the patients receiving the implants were middle-aged or elderly and because the morphology of the biting surface on the prosthetic restorations had become small. More-

Table 6-1 Change in Probing Depth due to implantation (mm)

No.	3 M	6 M	1 Y	2 Y	3 Y	4 Y	5 Y	6 Y	7 Y	8 Y	9 Y	10 Y	11 Y	12 Y
1 (M)	2	1.5	1.5	1.5	1.5	1.5	1.5	0.5	0.5	1	1	1	1	1
1 (D)	2	2	2	2	2	1.5	1.5	0.5	0.5	0.5	0.5	1	1	1
2 (M)	2	1.5	1.5	1.5	1.5	1	1	1	1	1	1	1	1	1
2 (D)	3	2	2	2	2	2	1.5	2	1.5	1.5	1.5	1.5	1.5	1.5
3 (M)	2	2	1	1	1	1	1	1	1	1	1	1	1	1
3 (D)	2.5	2	2	2	2	1.5	1.5	1.5	1	1	1	1	1	1
4 (M)	3	2	2	2	2	1.5	1.5	1.5	1.5	1.5	1	1	1	1
4 (D)	3	2.5	2.5	2	2	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5
5 (M)	3	3	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
5 (D)	3	3	2.5	2	2	2	1.5	1.5	1.5	2	2	2	2	
6 (M)	2	2	2	1.5	1.5	1.5	1.5	1.5	2	2	1.5	1.5	1.5	
6 (D)	2	2	2	1.5	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
7 (M)	2	2	1	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
7 (D)	2.5	2	1.5	1.5	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
8 (M)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1	1	1	
8 (D)	2	2	2	2	2	2	1.5	1.5	1	1	1	1	1	
9 (M)	2.5	2	2	1.5	1.5	1.5	1	1	1	1	1	1	1	
9 (D)	2.5	2.5	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1	
10 (M)	2.5	2	2	1.5	1.5	1.5	1	1	1	1	1.5	1	1	
10 (D)	2.5	2	2	1.5	1.5	1.5	1	1	1	1	1	1	1	
11 (M)	3	2.5	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
11 (D)	3	2.5	2.5	2	1.5	1.5	2	2	1.5	1.5	1.5	1.5	1.5	
12 (M)	2	2	2	1.5	1.5	1.5	1	1	1	1	1	1	1	
12 (D)	2.5	2	2	1.5	1.5	1.5	1	1	1	1	1	1	1	
13 (M)	3	2	2	1.5	1.5	1.5	1.5	2	1.5	1.5	1.5	1.5	1.5	
13 (D)	3	2	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
14 (M)	3	2.5	2.5	2.5	2.5	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
14 (D)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
15 (M)	2	2	2	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
15 (D)	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
16 (M)	2.5	2	2	1.5	1.5	1.5	1.5	1	1	1	1	1	1	
16 (D)	2.5	2	2	2	1.5	1.5	1.5	1.5	1	1	1	1	1	
17 (M)	2	2	2	2	1.5	1.5	1.5	1.5	1	1	1	1		
17 (D)	2.5	2.5	2	2	2	1.5	1.5	1.5	1.5	1	1	1		
18 (M)	2.5	2	1.5	1.5	1.5	1	1	1	1	1	1	1		
18 (D)	2.5	2	1.5	1.5	1.5	1	1	1	1	1	1	1		
19 (M)	1.5	1	1	1	1	1	1	1	1	1	1	1		
19 (D)	1.5	1	1	1	1	1	1	1	1	1	1	1		
20 (M)	2	1.5	1	1	1	1	1	1	1	1	1	1		
20 (D)	1.5	1.5	1	1	1	1	1	1	1	1	1	1		

(M) : Medical Site of the Implant (D) : Distal Site of the Implant
Follow-up time (M ; month, Y ; year)

Table 6-2 Change in Probing Depth due to implantation (mm)

No.	3 M	6 M	1 Y	2 Y	3 Y	4 Y	5 Y	6 Y	7 Y	8 Y	9 Y	10 Y	11 Y	12 Y
21 (M)	2.5	2	2	1.5	1	1	1	1	1	1	1	1		
21 (D)	2.5	2	2	1.5	1.5	1	1	1	1	1	1	1		
22 (M)	2	2	1.5	1.5	1.5	1	1.5	1.5	1	1	1	1		
22 (D)	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5		
23 (M)	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5		
23 (D)	2.5	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5		
24 (M)	1.5	1.5	1	1.5	1	1	1	1	1	1	1	1		
24 (D)	1.5	1.5	1.5	1.5	1	1	1	1	1	1	1	1		
25 (M)	2.5	2	1	1.5	1	1	1	1.5	1.5	1.5	1.5	1.5		
25 (D)	2.5	2	1	1	1	1	1	1	1	1	1	1		
26 (M)	2	2	1.5	1.5	1.5	1.5	1	1	1	1	1	1		
26 (D)	2	1.5	1.5	1.5	1	1	1	1	1	1	1	1		
27 (M)	2.5	2	2	1.5	1.5	1	1.5	1	1	1	1	1		
27 (D)	2.5	2	1.5	1.5	1.5	1	1	1	1	1	1	1		
28 (M)	3	2	2	1.5	1.5	1	1	1	1	1	1	1		
28 (D)	3	2.5	2	2	1.5	1	1	1	1	1	1	1		
29 (M)	2.5	1.5	1.5	1.5	1	1.5	1.5	1.5	1.5	1.5	1.5			
29 (D)	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5			
30 (M)	3	3	2	2	1.5	2	1.5	1.5	1.5	1.5				
30 (D)	3	3	2.5	2	2	2	2	1.5	1.5	1.5				
31 (M)	2.5	2.5	2	1.5	1	1	1	1	1	1				
31 (D)	2.5	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5				
32 (M)	2.5	2.5	2.5	2	2	1.5	1.5	1.5	1.5					
32 (D)	2.5	2.5	2.5	2	2	1.5	1.5	1.5	1.5					
33 (M)	2	1	1	1	1.5	1.5	1.5	1.5						
33 (D)	2	1	1	1	2	1.5	1.5	1.5						
34 (M)	2	1.5	1	1	1	1	1	1						
34 (D)	2	1	1	1	1	1	1	1						
35 (M)	2.5	2	1.5	1	1	1	1	1						
35 (D)	2	1.5	1.5	1	1	1	1	1						
36 (M)	2	2	1.5	1.5	1.5	1	1							
36 (D)	2	1.5	1.5	1	1	1	1							
37 (M)	2.5	2.5	2	2	1.5	1.5	1.5							
37 (D)	2.5	2.5	2	2	1.5	1.5	1.5							
38 (M)	2.5	2	1.5	1	1	1.5	1.5							
38 (D)	2.5	2	1.5	1.5	1.5	1.5	1.5							
39 (M)	3	2	1.5	1.5	1	1	1							
39 (D)	2.5	2	2	1.5	1.5	1.5	1.5							
40 (M)	2	1.5	1	1	1	1	1							
40 (D)	2	1.5	1	1	1	1	1							

(M) : Medical Site of the Implant (D) : Distal Site of the Implant
Follow-up time (M ; month, Y ; year)

over, we believe that from the standpoint of occlusal force, restoration of chewing ability was attained by adaptation to the implant.

The large majority of patients showed an increase in occlusal force after 1 year post-implantation, and we found that an increase in occlusal force on the non-implant side tended to accompany an increase in occlusal force on the implant side. These results support the reports of Kakitani[15] and Haraldsonn[16] that occlusal force in creases as the period of time after implantation increases. In the case of natural teeth, the main tactile sensations are in the muscles and mandibular joints when the occlusal force is large[17-19] and dental prostheses with implants increase the amount of muscular activity[20]. In the present study, the occlusal force on the healthy side tended to increase as the occlusal force on the implant side increased, thereby suggesting that the load on the jaw bone via the implant may activate the various organs of the oral cavity such as the chewing muscles. Moreover, the increase in occlusal force in most patients was observed after 1 year had passed, however this did not correspond with the patients' perception of the time required for restoration of chewing ability. The reason for this discrepancy is unclear, but may be the result of the patient's perception of the restoration of chewing ability being related to the patient's QOL. Moreover, we considered that the comparisson of occlusal force between implant prothesis and commonly prothesis was a theme to be solved for implant dentistry.

Peri-implant inflammation is a problem related to post-implantation maintenance. We evaluated the condition of the peri-implant gingiva using gingival index, Periotoron units and probing depth according to commonnly examination for periodontal gingiva. Our results suggest that the peri-implant gingiva remains stable, but because there have been scattered reports of poor plaque control and loss of retention[20,21], we believe that the important factors in the long-term clinical prospects are whether recalls for maintenance are established and whether the patient understands the importance of brushing.

The results of the present study suggest that long-term stability can be expected with HAP implants, and at present a bone-healing, osseointegrating implant without mediation by surrounding connective tissue is ideal.

However, periodontal ligament tissue is missing in bone-healing, osseointegrating implants, and therefore the damping effect of the periodontal ligament on chewing is lacking. Under these conditions we cannot expect the neurological regulation of chewing, which is based on the oral tactile sensory mechanism, to function normally. The sensibility of the periodontal ligament plays an important role in regulating chewing force and occlusal force, particularly in terms of the pain threshold. Thus, the absence in peri-implant tissue of a site for sensory input to compensate for the role of the periodontal ligament is an interesting clinical problem associated with chewing ability.

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