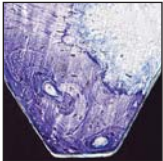


A Study of 275 Retrieved Brånemark Oral Implants



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The aim of this report was to describe the bone tissue response to Brånemark oral implants retrieved from patients. The material consisted of consecutively received Brånemark threaded oral implants and related patient data provided by clinicians. The implant samples were processed into undecalcified sections for evaluation under the light microscope. The analysis demonstrated a lower percentage of bone-to-implant contact for the unloaded implants as compared to the loaded implants. When the threads were divided into four different regions, the loaded implants had a lower percentage of bone-contacting length at the thread top as compared to the other three regions. (Int J Periodontics Restorative Dent 2005;25:425–437.)

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The replacement of missing teeth with implant-supported prosthetic restorations is a treatment modality that has been growing extensively during the last decades. The use of implants for this application began in the mid-1960s. Clinical follow-up data show a high success rate over a long time period.^{1–3} However, a small number of implants failed, either because of primary failure (bone anchorage was never achieved) or secondary failure (loss of initially established bone anchorage). Histo-morphometric evaluation is an excellent way to describe the tissue response to retrieved oral implants. Even clinically successful implants may be histologically analyzed, eg, in postmortem specimens.

The Retrieval Laboratory at the Department of Biomaterials/Handicap Research, Göteborg University, has continuously received retrieved implants for evaluation from all over the world. This report includes consecutively received samples of Brånemark oral implants (Nobel Biocare) that have been in place for up to 16 years. In the present report, implants placed in irradiated or

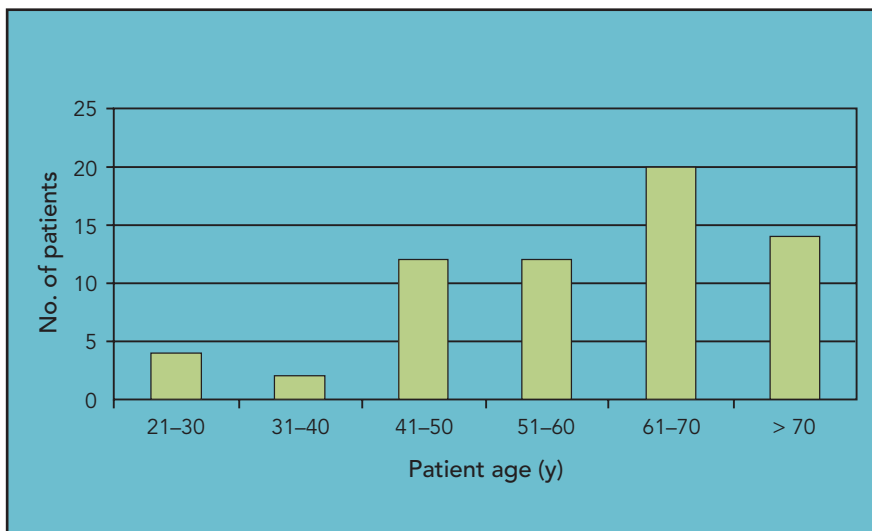


Fig 1 Patient age at time of implant removal ($n = 64$). In 67 cases, patient age was not disclosed.

grafted bone were excluded; they will be reported separately.

The aim of this report was to quantitatively and qualitatively describe the bone tissue response to Brånemark oral implants retrieved from patients.

Method and materials

The material consisted of consecutively received Brånemark oral implants and related patient data provided by clinicians. The implants were threaded and made of commercially pure titanium (cpTi). The implant designs used in this patient material were standard and self-tapping implants, mainly 3.75 mm in diameter.

Of the 275 implants retrieved from 167 patients included in this

study, 216 implants were stable at the time of removal and suitable for histologic evaluation of the bone tissue response in undecalcified specimens. The remaining 59 implants were, when possible, evaluated with other techniques, eg, histologic evaluation of decalcified specimens and analysis of the implant oxide layer. Investigations of the latter 59 implants have yet not been completed and are, therefore, not presented in this paper.

Of the 216 implants subjected to histologic evaluation according to the methods presented, the bone tissue response was quantitatively and qualitatively evaluated for 196 implants; in addition, another 20 implants were evaluated only qualitatively.

Stated reasons for removal of the 216 implants subjected to histo-

logic evaluation varied but included patient death ($n = 15$), inadequate patient adaptation ($n = 37$), bone resorption/infection/inflammation ($n = 31$), trauma ($n = 2$), pain ($n = 4$), overload ($n = 1$), hyperesthesia ($n = 1$), mechanical failure ($n = 57$), and iatrogenic reasons ($n = 6$). For 62 implants, the reason for removal was not disclosed.

The 216 evaluated implants were retrieved from 131 patients. The distribution between gender was known for 108 of the patients (82%), with 36 men (27%) and 72 women (55%). Patient age at time of removal was known for approximately 50% of the patients ($n = 64$; age of 67 patients was unknown) and ranged from 22 years to 83 years. Patients' ages at time of removal are presented in Fig 1.

The time in situ for the implants was known for 136 (63%) of the 216 implants and varied from 4 to 192 months. One hundred forty-two (65%) of the 216 implants had been loaded, 21 (10%) implants remained unloaded, and for 53 (25%) of the implants there was no information about loading. Time in situ and loading time in relation to number of implants are presented in Table 1.

At the time of removal, the implants were immersed in 4% neutral buffered formaldehyde for fixation and transported to the Department of Biomaterials/Handicap Research for further preparations. Following fixation, the samples were dehydrated in solutions with increasing concentrations of ethanol (70% to 100%) and prefiltered in diluted resin; they were then infiltrated in

pure resin by stirring under vacuum conditions. Finally, the samples were embedded in either LR White resin (London Resin) or Technovit 7200 VLC/light-curing resin (Kulzer). With Exakt sawing and grinding equipment, the cured specimens were divided at the midsection, along the long axis of the implant. The surfaces were evenly ground, and a piece of acrylic glass of known thickness was glued to the surface of the sample. Initially, a thick section (150 to 200 μm) was cut. The sections were then ground to a final thickness of about 10 μm .⁴ Routinely, the sections were stained in toluidine blue mixed with pyronin G. Preparation and staining techniques followed the recommendations by Donath and Breuner.^{5,6} These procedures are routinely carried out for all retrieved human samples at the Department of Biomaterials/Handicap Research.

The histologically stained and undecalcified sections were quantitatively and qualitatively evaluated using a light microscope. The evaluations were performed using a Leitz Aristoplan light microscope equipped with a Microvid unit, coupled to a personal computer. Quantitative analyses were performed directly in the eyepieces of the microscope with an objective of $\times 10$ and zoom (up to $\times 2.5$) when needed.

The entire thread length and then the bone-contacting lengths were outlined; the bone-contacting lengths were divided by the thread length to calculate the percentage of bone-to-metal contact. The bone

Time	Implants	
	No. in situ (n = 136)*	No. loaded (n = 68) [†]
< 3 mo	–	1
3 to 6 mo	15	3
7 to 12 mo	5	1
13 to 18 mo	4	6
19 to 24 mo	8	3
2 to 3 y	11	9
3 to 4 y	18	11
4 to 5 y	17	10
5 to 10 y	42	19
10 to 15 y	13	3
> 15 y	3	2

*For 80 implants the time in situ was not disclosed.

[†]For 74 loaded implants the time was not disclosed.

area was measured by first outlining the total area bounded by the thread and then marking the total area occupied by bone inside the thread; the percentage of bone area inside the thread was calculated by dividing the area of bone inside the thread by the total area bounded by the thread. All threads on both sides of the implant with an entire thread length and with bone tissue in contact or bone tissue within the thread were measured. A mean value for the three best consecutive threads was calculated per implant for both bone-to-metal contact and bone area within the thread.

An estimate of individual threads' bone-contacting lengths,

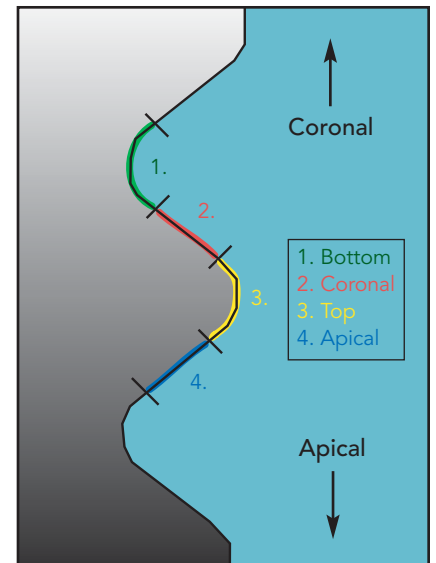


Fig 2 Four different regions within the implant threads were subjected to estimation of percentage of bone-contacting lengths: 1 = Top of the thread; 2 = coronal part of the thread; 3 = bottom of the thread; 4 = apical part of the thread.

with the threaded area divided into four different regions, was performed on survey color prints (magnification $\times 35$). The percentage of bone-contacting length was estimated for the bottom of the thread, the coronal part of the thread, the top of the thread, and the apical part of the thread. All available threads on both sides of the implant that had an entire thread length with tissue in contact with the implant were evaluated. A mean value for each of the four regions of the thread was calculated per implant (Fig 2).

The qualitative analyses were performed with objectives from $\times 1.2$ to $\times 40$ plus zooming, giving a magnification range of $\times 400$ to $\times 800$.

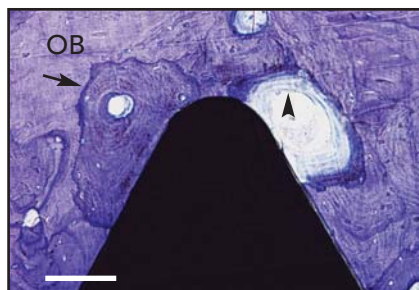


Fig 3 Mature and newly formed bone in contact with the implant. Arrows indicate the cement line; the arrowhead indicates the osteoid rim (undecalcified section stained with toluidine blue; thickness 10 μ m, bar = 100 μ m). OB = old bone.

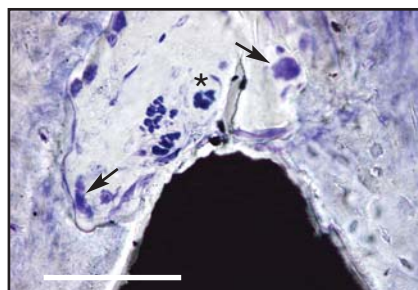


Fig 4 Bone-resorptive cavity with osteoclasts (arrow). A blood vessel (asterisk) was observed in close vicinity to the implant. Bar = 100 μ m.

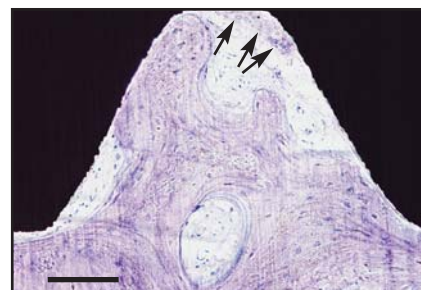


Fig 5 Multinuclear giant cell in contact with the implant (arrows). Bar = 100 μ m.

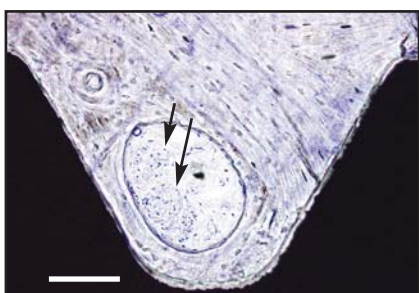
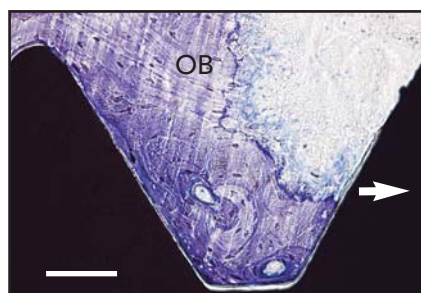


Fig 6 (left) Nerve bundles (arrows) in close proximity to the implant surface. Bar = 100 μ m.

Fig 7 (right) In general, the coronal bone surface had a resorptive appearance. Bar = 100 μ m. OB = old bone; arrow indicates coronal direction.



Results

The reason for removal was known for 71% of the 216 histologically evaluated implants. The two main reasons reported were host tissue reactions and mechanical failures of implant pillar parts (18% and 26%, respectively). The reason for removal of the remaining 27% of the implants can be divided into inadequate patient adaptation (17%), patient death (7%), and iatrogenic reasons (3%). All 216 implants included in this study were clinically stable at the time of removal.

The qualitative histologic investigation of the sections reveal-

ed bone tissue in the threads of the implants and variations in the degree of direct bone-to-implant contact. Generally, the bone-to-implant contact consisted of mature bone and/or newly formed immature bone, with the latter indicated by a darker staining reaction and its histologic appearance, ie, bone of a more woven character. Occasionally, osteoid seams lacking osteoblast rims and bone-resorptive cavities with osteoclasts could be observed (Fig 3). Blood vessels close to the implant surface were detected in a majority of the sections (Fig 4). Macrophages and other inflammatory cells were com-

monly visible in the sections. At implant surfaces where there was soft tissue contact, multinuclear giant cells could be detected in a few cases (Fig 5). Nerve bundles in close proximity to the implant surface were detected in a few sections; one was from an implant that had been removed because of pain (Fig 6). In a majority of the sections from implants removed secondary to bone resorption, the first bone-to-implant contact was found at or below 3 mm from the flange. At the coronal bone surface, signs of bone resorption were observed (Fig 7). In sections from implants that had been removed because

Table 2 Data for unloaded implants

Gender	Age at removal (y)	Jaw	Time in situ (mo)	Loading time (mo)	Direct bone contact (%)	Bone area in threads (%)	Reason for removal
—	—	—	—	0	54	62	—
F	56	Mand	6	0	85	93	Death
F	56	Mand	6	0	73	86	Death
F	56	Mand	6	0	86	89	Death
—	—	—	—	0	—	91	—
—	—	—	—	0	—	89	—
F	46	Mand	9	0	59	85	Pain
F	46	Mand	9	0	58	88	Pain
F	25	Max	12	0	95	98	Iatrogenic reason
M	67	Mand	5	0	35*	76*	Inadequate patient adaptation
M	67	Mand	5	0	9	63	Inadequate patient adaptation
M	67	Mand	4	0	19*	48	Inadequate patient adaptation
M	67	Mand	4	0	—	—	Inadequate patient adaptation
M	67	Max	5	0	—	—	Inadequate patient adaptation
M	67	Max	5	0	—	—	Inadequate patient adaptation
M	67	Max	5	0	—	—	Inadequate patient adaptation
M	67	Max	5	0	29	83	Inadequate patient adaptation
M	67	Max	5	0	—	—	Inadequate patient adaptation
M	67	Max	5	0	—	—	Inadequate patient adaptation
—	—	Mand	6	0	22 [†]	48*	Bone loss/pain
F	25	Max	6	0	16	74	Inadequate patient adaptation

*Only one thread available for analysis.

[†]Only two threads available for analysis.

— = information not available.

of inadequate patient adaptation following 4 to 5 months in situ, bone-to-implant contact was low as compared with other samples with corresponding time in situ. In general, for these sections there was soft tissue contacting the implant. Few inflammatory cells could be detected in these sections, and bone chips and other remnants from site preparation were present. The activity in the bone tissue was low, as indicated by the limited apposition and remodeling of the bone.

Histomorphometric analyses were affected by the trephining procedure at the time of removal,

which in some cases had resulted in cuts through the implants, thereby preventing analysis of the entire implant. The number of threads available for measurements of direct bone-to-implant contact and bone area inside the threads varied from 1 to 56 in individual implants. The aim was to perform comparative calculations in the three best consecutive threads on each implant and then present the mean value per implant. However, in some cases fewer consecutive implant threads were available, as indicated in Tables 2 to 5.

The results of the histomorphometric analyses are presented in

Tables 2 to 5, with the implants divided into the following four groups: unloaded implants, implants with no information regarding loading, loaded implants with no stated loading time, and implants with stated loading time.

For the 21 unloaded implants, the reason for removal was known for 18 implants (86%); 3 of the implants were retrieved post-mortem, 2 were removed because of pain, 1 was removed because of bone loss, and 1 was removed for an iatrogenic reason, ie, malalignment. The remaining 11 implants were removed because of inadequate patient adaptation (Table 2).

Table 3 Data for implants with no information regarding loading

Gender	Age at removal (y)	Jaw	Time in situ (mo)	Loading time (mo)	Direct bone contact (%)	Bone area in threads (%)	Reason for removal
F	45	—	—	?	79	90	—
F	53	—	—	?	—	97 [†]	—
F	56	—	—	?	—	—	—
F	51	—	—	?	89	93	—
F	67	—	—	?	21 [†]	77 [†]	—
F	22	—	—	?	—	78	—
M	44	—	—	?	48	63	—
M	44	—	—	?	69	70	—
F	—	—	—	?	91	91	—
F	—	—	—	?	—	—	—
F	—	—	—	?	48	58	—
F	—	—	—	?	79	78	—
F	—	—	—	?	—	79	—
—	—	—	—	?	—	94 [†]	—
—	—	—	—	?	43	57	—
M	—	—	—	?	—	—	—
—	—	—	36	?	38	72	—
F	—	—	—	?	95	96	—
F	63	—	—	?	33	80	—
F	63	—	—	?	—	—	—
F	—	—	—	?	—	—	—
F	73	—	96	?	79*	93*	—
M	61	—	—	?	29	80	—
M	61	—	—	?	73	84	—
M	61	—	—	?	24	39	—
F	—	—	—	?	61	87	iatrogenic reason
F	—	Mand	—	?	76	91	—
F	—	Mand	—	?	64	76	—
—	—	—	—	?	51	62	—
F	62	Mand	—	?	38	83	—
F	62	Mand	—	?	—	—	—
F	62	Mand	—	?	—	—	—
F	—	—	81–93	?	100	88	Bone resorption
F	—	Mand	—	?	87	96	Infection
—	—	—	—	?	85	74	—
F	56	—	93	?	83	76	—
F	—	—	—	?	91	83	Pain
F	65	—	74	?	89	96	—
F	74	—	23	?	49	79	—
—	—	—	—	?	30	72	—
F	64	—	—	?	75	88	—
F	64	—	—	?	81	91	—
F	64	—	—	?	76	90	—
F	—	—	—	?	98 [†]	99 [†]	—
—	—	—	—	?	99	98	—
—	—	—	> 120	?	89	96	—
F	24	—	—	?	92	93	—
F	—	—	39	?	96	97	—
—	—	—	—	?	94	95	—
—	—	—	—	?	17	45	—
M	—	—	58	?	87	91	iatrogenic reason
—	—	—	—	?	64	90	iatrogenic reason
F	—	—	—	?	78	93	—

*Only one thread available for analysis.

†Only two threads available for analysis.

— = information not available.

The time in situ was known for 18 implants and varied from 4 to 12 months.

In six sections, a histomorphometric calculation was not possible, and in sections from an additional two implants the percentage of bone area within the threads was calculated, but the percentage of bone-to-implant contact was not measured because of technical reasons, such as intense staining of the tissue-implant interface and/or separation of tissue and implant in the sections. In three sections, fewer than three consecutive threads were available for the calculations. Based on measurements of the 163 individual implant threads, the mean bone-to-implant contact for the three best consecutive threads in 13 implants was 49% (range 9% to 95%), and the mean bone area within the three best consecutive threads for 15 implants was 78% (range 48% to 98%).

In the group of 53 implants with no information regarding loading (Table 3), there was limited information relating to the patient and the implant treatment. In 6 (11%) of the 53 cases, the reason for removal was known: three of the implants were removed due to iatrogenic reasons (ie, implant not needed, implant malpositioned, and malalignment) and one implant was removed because of bone resorption, infection, or pain, respectively. The time in situ was known for 9 of the 53 implants and ranged from 23 to more than 120 months.

Because of technical reasons, a histomorphometric calculation was not possible for 7 of the 53 sec-

tions. In addition, in sections from four implants, the percentage of bone area inside the threads was calculated but it was impossible to measure the direct bone-to-implant contact. However, all of these sections were subjected to qualitative evaluation. In five sections, fewer than three consecutive threads were available for calculations. Based on measurements of the 392 individual threads, the mean bone-to-implant contact for the three best consecutive threads in 42 implants was 69% (range 17% to 100%), and the mean bone area within the three best consecutive threads in 46 implants was 83% (range 39% to 99%).

Seventy-four implants were loaded but no loading time was stated (Table 4). The reason for removal was known for 67 (91%) of the 74 implants: 36 implants were removed because of mechanical reasons, 16 were removed because of bone resorption; 1 implant was removed because of inflammation, infection, or hyperesthesia, respectively; 10 were removed because of inadequate patient adaptation; and 2 were postmortem cases. The time in situ was known for 50 implants (68%) with a mean of 80 months (range 12 to 192 months).

In two of the sections, histomorphometric calculation was not possible because of technical reasons. In seven sections, fewer than three consecutive threads were available for calculation with respect to bone-to-metal contact and bone area within threads. Based on the measurements of the 508 individual

threads available for analysis, the mean bone-to-metal contact for the three best consecutive threads in 72 implants was 76% (range 6% to 100%), and the mean bone area within the three best consecutive threads in 72 implants was 84% (range 42% to 98%).

For 68 implants the loading time was known (Table 5). The reason for removal was known for 63 (93%) of the implants: 21 implants were removed for mechanical reasons; 16 were removed because of inadequate patient adaptation; 10 were postmortem cases; 8 were removed following bone resorption/loss; 2 implants were removed because of infection, trauma, and iatrogenic reasons (ie, malposition of implant and paresthesia), respectively; 1 implant was removed because of pain and overload, respectively. The time in situ was known for 59 (87%) of the 68 implants, with a mean of 62 months (range 7 to 192 months). The mean loading time for the 68 implants was 55 months (range 2 to 189 months).

Because of technical reasons, a histomorphometric calculation was not possible for five of the sections. In addition, for sections from three implants, the percentage of bone area within the threads was calculated but it was impossible to measure the percentage of bone-to-implant contact. In three sections, fewer than three consecutive threads were available for calculation. Based on measurements of all 821 individual threads, the mean bone-to-implant contact for the three best consecutive threads in 60 implants was 75% (range 30% to 100%), and the mean bone area within the three best

Table 4 Data for loaded implants with unknown loading time

Gender	Age at removal (y)	Jaw	Time in situ (mo)	Loading time (mo)	Direct bone contact (%)	Bone area in threads (%)	Reason for removal
F	51	—	—	?	80	76	Mechanical failure
F	51	—	—	?	76	71	Mechanical failure
F	64	Max	192	?	62	76	Inadequate patient adaptation
F	50	Mand	168	?	74	81 [†]	Bone resorption
M	47	Max	132	?	77	79	Mechanical failure
F	37	Mand	108	?	84	89	Death
F	37	Mand	108	?	93	95	Death
F	71	Mand	30	?	90	74	Inadequate patient adaptation
F	71	Mand	30	?	90	90	Inadequate patient adaptation
F	71	Mand	30	?	93	96	Inadequate patient adaptation
F	71	Mand	30	?	87	96	Inadequate patient adaptation
F	49	Mand	54	?	95	96	Bone resorption
F	49	Mand	54	?	95	88	Bone resorption
F	49	Mand	54	?	81	94	Bone resorption
F	49	Mand	54	?	92	92	Bone resorption
F	68	Mand	144	?	92	91	Mechanical failure
F	—	Mand	84	?	59	84	Bone resorption
F	62	Mand	48	?	63*	87*	Bone resorption
F	74	Mand	72	?	48 [†]	42 [†]	Bone resorption
F	74	Mand	72	?	52	74	Bone resorption
F	45	Mand	12	?	57	89	Bone resorption
F	—	Max	> 36	?	—	—	Inflammation
F	50	Max	180	?	91	94	Mechanical failure
F	50	Max	180	?	80	84	Mechanical failure
M	—	Mand	—	?	65	81	—
M	—	Mand	—	?	67	88	—
M	—	Mand	—	?	53	75	—
M	75	Mand	74	?	90	89	Mechanical failure
F	64	Mand	38	?	65	92	Hyperesthesia + allodynia
F	—	—	—	?	68	79	Mechanical failure
F	—	—	36–48	?	75	90	Mechanical failure
F	—	—	36–48	?	82	78	Mechanical failure
F	47	—	—	?	65	80	Mechanical failure
F	47	—	—	?	93	96	Mechanical failure
M	—	—	24	?	86	94	Mechanical failure
M	—	Mand	—	?	75	92	Mechanical failure
M	—	Mand	—	?	81	88	Mechanical failure
—	70	—	96	?	—	—	Mechanical failure
F	—	—	84	?	81	89	Mechanical failure
—	—	—	—	?	95	95	Mechanical failure
F	62	Max	26	?	86	91	Inadequate patient adaptation
F	62	Max	26	?	58	69	Inadequate patient adaptation
F	62	Max	26	?	84	54	Inadequate patient adaptation
F	62	Max	27	?	60	78	Inadequate patient adaptation
F	62	Max	27	?	68	85	Inadequate patient adaptation
—	—	Max	—	?	6*	75*	Bone resorption
—	—	Max	—	?	42	82	Bone resorption
—	—	Max	—	?	67	62	Bone resorption
—	—	Max	—	?	71	82	Bone resorption
—	—	Max	—	?	36 [†]	81 [†]	Bone resorption
M	—	—	75	?	90	93	Mechanical failure
M	69	—	120	?	94	92	Mechanical failure
M	69	—	120	?	95	95	Mechanical failure
M	69	—	120	?	100	86	Mechanical failure
F	57	Max	> 60	?	94	74	—
F	57	Max	> 60	?	99	88	—
F	57	Max	> 60	?	93	90	—
M	76	Max	65	?	88	92	—
M	—	—	—	?	58	86	Mechanical failure
F	—	Mand	45	?	81	90	Infection
M	—	—	—	?	78	85	Mechanical failure
F	79	—	> 120	?	26*	36	Mechanical failure
F	79	—	> 120	?	81	88	Mechanical failure
F	56	—	91	?	98	98	Mechanical failure
M	36	—	—	?	81	93	Mechanical failure
F	56	Mand	—	?	51	66	Bone resorption
M	—	—	58	?	69	82	Mechanical failure
M	—	Mand	—	?	84	87	Mechanical failure
M	—	Max	—	?	83	81	Mechanical failure
M	—	Mand	—	?	67	85	Mechanical failure
—	—	—	180	?	87	97	Mechanical failure
F	—	Max	156	?	74 [†]	83 [†]	Mechanical failure
—	70	—	168	?	89	98	Mechanical failure
F	—	—	—	?	49	54	Mechanical failure

*Only one thread available for analysis.

†Only two threads available for analysis.

— = information not available.

Table 5 Data for loaded implants with stated loading time

Gender	Age at removal (y)	Jaw	Time in situ (mo)	Loading time (mo)	Direct bone contact (%)	Bone area in threads (%)	Reason for removal
—	54	Max	—	24	60	86	Bone resorption
F	72	Max	120	114	30	42	Mechanical failure
—	—	—	39	30	31*	87*	—
M	63	Max	108	100	67	86	Mechanical failure
F	69	Mand	192	189	60*	80*	Mechanical failure
F	69	Mand	192	189	56	92	Bone resorption
F	71	Mand	72	69	81	89	Bone resorption
F	71	Mand	72	69	85	92	Bone resorption
F	46	Mand	26	23	53	93	Mechanical failure
F	59	Mand	102	98	91	94	Mechanical failure
F	59	Mand	102	98	56	76	Mechanical failure
F	59	Mand	102	98	90	87	Mechanical failure
M	—	—	54	42	71	96	Mechanical failure
M	—	Mand	50	30	45	81	Bone loss
M	74	Mand	62	55	93	96	Death
M	74	Mand	62	55	—	83	Death
M	74	Mand	62	55	—	97	Death
M	74	Mand	62	55	88	94	Death
M	74	Mand	62	55	100	97	Death
M	74	Mand	56	51	100	98	Death
M	74	Mand	56	51	99	98	Death
M	74	Mand	56	51	97	97	Death
M	74	Mand	56	51	97	98	Death
M	74	Mand	56	51	100	98	Death
M	—	Max	58	36	78	91	Mechanical failure
F	83	Mand	21	18	75	92	Inadequate patient adaptation
F	83	Mand	21	18	71	84	Inadequate patient adaptation
F	83	Mand	21	18	92	94	Inadequate patient adaptation
F	83	Mand	21	18	62	88	Inadequate patient adaptation
—	—	Max	—	42	44	49	Trauma
—	—	Max	—	42	—	—	Trauma
F	47	Mand	7	2	97	89	Iatrogenic reason
F	—	Mand	57	18	96	91	Pain
F	—	Mand	—	48	54	78	Bone resorption
F	—	Mand	—	48	50	70	Bone resorption
F	—	Max	50	41	87	99	Iatrogenic reason
M	—	—	66	60	—	—	—
F	58	Mand	24	19	33	67	Bone resorption
M	—	—	30–41	36	—	—	Mechanical failure
F	—	Mand	93	78	92	87	Mechanical failure
M	—	—	—	108	46	68	Mechanical failure
M	67	Max	84	75	63	92	Mechanical failure
M	—	Max	87	75	80	91	Mechanical failure
F	64	Mand	39	28	86	96	Inadequate patient adaptation
F	64	Mand	39	28	81	93	Inadequate patient adaptation
F	64	Mand	39	28	93	98	Inadequate patient adaptation
M	—	Max	51	43	98	94	Mechanical failure
—	—	Max	—	> 60	94	97	—
—	—	Max	—	> 60	—	—	—
M	—	Max	94	85	94	90	Mechanical failure
M	—	Max	94	85	99	87	Mechanical failure
M	—	Max	94	85	90	94	Mechanical failure
F	47	Mand	76	71	63	83	Overload
F	69	—	18	4	—	—	Inadequate patient adaptation
F	69	—	18	4	—	66	Inadequate patient adaptation
F	69	—	18	4	52	69	Inadequate patient adaptation
F	—	Mand	23	17	95	96	Mechanical failure
M	61	Max	71	61	88	92	Mechanical failure
M	54	Max	40	34	76	91	Inadequate patient adaptation
M	54	Max	40	34	54	83	Inadequate patient adaptation
M	54	Mand	43	37	69	90	Inadequate patient adaptation
M	54	Mand	43	37	77	86	Inadequate patient adaptation
M	54	Mand	43	37	87	98	Inadequate patient adaptation
M	54	Mand	43	37	77	87	Inadequate patient adaptation
F	—	Mand	—	144	91	98	Mechanical failure
F	76	—	132	130	49	76	Infection
F	76	—	132	130	42 [†]	80 [†]	Infection
M	75	—	18	10	45	82	—

*Only one thread available for analysis.

† Only two threads available for analysis.

— = information not available.

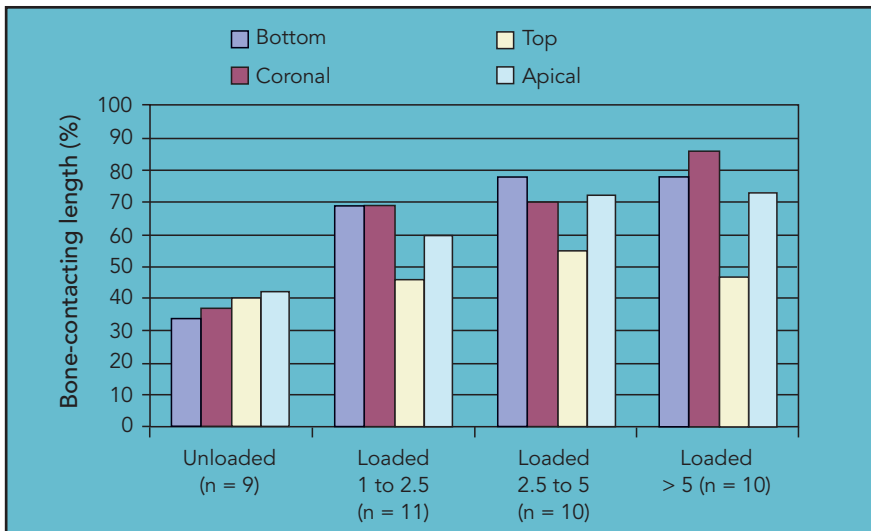


Fig 8 Bone-contacting length for the four different groups of implants.

consecutive threads in 63 implants was 84% (range 42% to 98%).

The estimates of bone-contacting lengths in the four different regions of the individual threads were performed with the implants divided into four groups: unloaded, loaded 1 to 2.5 years, loaded 2.5 to 5 years and loaded more than 5 years. Prerequisites for this estimation were that each section should have non-faded staining along the entire implant as well as tissue within the threads. This resulted in evaluation of color prints from 40 sections with the following distribution: 9 unloaded implants, 11 implants loaded 1 to 2.5 years, 10 implants loaded 2.5 to 5 years, and 10 implants loaded more than 5 years. For the unloaded implants, there was a similar percentage of bone-contacting lengths for all four regions of the

thread. However, for the loaded implants, the top of the implant thread had a lower percentage of bone-contacting length as compared to the other three regions of the thread (Fig 8).

Discussion

The mean values in percentages for bone-to-implant contact and bone area within the threads reported in this paper were in the same range for the different groups, with the exception of a rather low bone-to-implant contact for the unloaded implants. The time in situ for the latter implants was short (mean value 6.6 months, with a range up to 12 months). The low bone-to-implant contact percentages are in accordance with results from an experimental study

demonstrating increased bone values for titanium screw-shaped implants over time.⁷ In the other groups, only 1 of 181 implants reported a time in situ shorter than 12 months. The percentages of bone-to-implant contact for the loaded implants in this study, (76% and 75%), as compared to the unloaded (49%), support the radiographic findings by Strid.⁸

The estimation of bone-contacting lengths for the different regions of the thread resulted in lower percentages as compared to the histomorphometric calculations. This can be explained by the fact that all available threads with tissue present were included in the evaluation, in contrast to only the three best consecutive threads with bone tissue present in the other histomorphometric calculations. The group of unloaded implants demonstrated lower percentages of bone-contacting lengths for all four thread regions compared to the loaded implants, indicating that bone remodels at the implant interface as a response to loading. The loaded implants that showed the lowest percentage of bone-contacting length at the top of the thread could be explained by stress concentration. The specific loading conditions of these implants remain unspecified, but because they had been prosthetically loaded, the loading must have been dynamic. Jemt et al⁹ reported on bone-contacting lengths at different regions of the thread in an experimental study with an introduced framework misfit. A significant positive correlation between increased preload, acting on

the implant, and percentage of bone-contacting length at the top of the thread was demonstrated. However, this study design aimed to induce a vertical force and not to mimic the clinical situation of prosthetically loaded implants.

Histologic reports in the literature of retrieved oral implants are often presented as case reports¹⁰⁻¹⁹ and hence provide limited information. However, Piattelli et al²⁰ and Stefflik et al²¹ have reported histologic observations on a large number of retrieved dental implants with the aim of defining causal determinants for implant failures. Piattelli et al reported on histologic observations from 230 retrieved dental implants of various designs. In their material, host tissue factors were incriminated as reasons for implant removal more frequently than bi-material problems. It was seldom possible to relate implant failure to psychologic matters. Stefflik et al reported on analyses obtained from 200 implant cases, including both dental and orthopedic devices, focusing on the results in relation to implant coatings. Their report stated that biologic failures of implants, ie, loss of bone support, connective tissue encapsulation, and inflammatory cell infiltrates, may be particularly attributed to implants with a time in situ of 10 years or longer. Failure of more recently placed implants was more often regarded as related to biomaterial failure.

Because the aim of the present study was to describe the bone tissue response to osseointegrated Brånemark oral implants with histo-

morphometric calculations, a prerequisite was stability at the time of removal. Thus, our material differs from studies that aim to define causal determinants for implant failure, ie, there was a lack of clinically diagnosed mobile implants, and several implants were removed because of inadequate patient adaptation as well as patient deaths.

Reports on histomorphometric analyses of retrieved dental implants of one and the same design are rare. Histologic findings (light microscopy and transmission electron microscopy) of 10 Brånemark implants retrieved from nine patients were reported by Esposito et al.²² All of the implants were secondary failures, ie, following loading with prosthetic restorations. The histologic observations, together with clinical and radiographic findings, indicated that two major etiologic factors might have been implicated in the failure process: excessive occlusal load in relation to the bone-supporting capacity and, in two cases, infection. Albrektsson et al²³ reported on 30 loaded Brånemark implants retrieved from 17 patients. The implants were all stable at the time of removal. Reasons claimed for retrieval were bone resorption in combination with soft tissue disorders, psychologic causes, implant fracture, and patient death. The mean value for both bone-to-implant contact and bone area within the threads for the three best consecutive threads was 82%. In addition, in the study, three implants that had not been loaded showed mean values for bone-to-implant contact and bone

area within the threads of 70% and 75%, respectively. The implants analyzed by Albrektsson et al are all included in the present material. However, for control purposes all histomorphometric calculations were recalculated in the present work. The histomorphometric calculations in our larger study based on 196 implants are in the same range as previous findings by Albrektsson et al, with the exception of the lower value for bone-to-implant contact in unloaded cases. However, the three unloaded implants in the study were all placed in the mandible in the same patient. In our material, we found a wide range of bone-to-implant contact percentages (9% to 86%), as well as for bone area within the threads (48% to 93%), for the nine unloaded implants retrieved from mandibles in four patients.

Piattelli et al²⁴ conducted a histologic analysis of 19 Brånemark System implants retrieved for different reasons. For implants removed because of mechanical failure, a bone-to-implant contact percentage of 72% was calculated. Two implants that were removed for bone overheating 3 months after placement showed bone sequestrum and a gap between implant and bone filled with lymphocytes and plasma cells. For implants removed because of peri-implantitis, an inflammatory infiltrate was observed in the peri-implant tissue with bacteria present on the coronal part of the implant. In implants retrieved because of mobility, a dense fibrous connective tissue with no inflammatory cells was found around the implants.

The implants removed because of mechanical failure in our study showed slightly higher percentages for bone-to-implant contact and bone area within the threads (79% and 86%, respectively), as compared to all loaded implants (76% and 84%, respectively). Our mean value for bone-to-implant contact for implants with a mechanical failure is in the same range as that reported by Piattelli et al,²⁴ taking into consideration that our calculations were based on the three best consecutive threads and the fact that Piattelli et al had slightly thicker specimens than ours (a situation known to result in higher bone-to-implant percentages). Infection was the reason given for removal of only four histologically evaluated implants in our study. Three of these implants were reported loaded, whereas for one device, information about loading was lacking. Two such implants showed bone-to-implant contact below 50%. However, the area of bone tissue within the threads was high for all four implants. All four samples showed evidence of marginal bone resorption with the first coronal bone-to-implant contact ranging from the first thread to half of the implant length.

Ivanoff et al,²⁵ when they examined micro-implants retrieved from human jaws, observed a difference in the amount of bone-to-implant contact and bone area within threads between implants placed in the maxilla and those placed in the mandible. In our study, the position was known for 119 implants with calculations of bone-to-implant contact

and/or bone area within the threads: 39 implants were placed in the maxilla, and 80 implants were placed in the mandible. The mean values of percentages of bone-to-implant contact and bone area within the threads were 71% and 83%, respectively, for maxillary implants and 79% and 86%, respectively, for implants placed in the mandible. These findings are in line with the observations of Ivanoff et al. However, the fact that the calculations were made on the three best consecutive threads, ie, usually the threads located in the cortical passage, worked in favor for higher percentages in the mandible. In conclusion, we believe that large material of available retrieved implants can be of some value to increase our knowledge about oral implant function. Having said this, we are also aware of some obvious shortcomings of a large implant material received from numerous clinicians, often with limited submitted information about the clinical conditions for the implants.

Acknowledgment

This study was supported by grants from the Swedish Research Council, the Wilhelm and Martina Lundgren Foundation, the Sylvan Foundation, and the Hjalmar Svensson Foundation.

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