JMM JAPAN MEDICAL MATERIALS

KiT NEWS

Consideration on Surface Properties of Implant
—Investigation on Potential of HA-coating—

Dr.Eiji Kato
HA vs.Ti Implant
Long-Term Success Rate
and Causes of Failure

Dr.Tetsuya Mizukami
Clinical Application of HA-coated Implants

HA vs. Ti Implant Long-Term Success Rate and Causes of Failure

Eiji Kato, Representative of ITDN-Tokyo
<Implant Center Nakameguro・Kato Dental Clinic>

Introduction

Numerous reports casting doubts on the long-term stability and prognosis of hydroxyapatite (HA)-coated implants have been published[1]. These reports point out that unstable HA coating elevates the sensitivity to bacterial infection, possibly leading to rapid bone breakdown or saucerization bone defect and that HA-coated implants have no features superior over titanium (Ti) implants[2]. However, the majority of these reports were anecdotal in nature, relying on the data from isolated case report[3]. These reports began to be published early in the 1990s, 5 years after 1984 when the clinical application of HA-coated implants was started, and they attributed the failure of this type of implant to the lack of long-term stability of the coating layer.

The present study was undertaken to review and verify these previous reports from 3 points of view.

I. Comparison between findings from statistical analysis of HA-coated thread type implants (implants kept placed for 5 years or longer among the 1157 HA-coated thread type implants bearing loads for 6 months longer; a type of implant adopted at multiple centers after 1995) and the findings from statistical analysis of Ti implants.

II. Classification of the bone defect patterns in relation to clinical symptoms in cases of implant failure among the subjects of this study and comparison with Ti implants.

III. Evaluation of long-term advantages and risks based on the overall assessment of histological features revealed by topography.

I.Report of the study

HA-coated implants are expected to enhanced osteointegration and appear to be useful, particularly in sites with poor bone quantity or quality. Initial success in the use of HA-coated implants resulted in increased frequency of their clinical use. However, despite their clinical application since 1984, only a small number of reports have been published on HA-coated implants. Further, a number of reports doubting the long-term stability and prognosis have been published. The most strongly criticized feature of clinical use of HA-coated implants is the lack of statistical reports endorsing the long-term stability of HA-coated implants. When conducting a survey on the long-term course of HA-coated implants, the following are important.

○The survey involves multiple implants.

○At least 5 years have elapsed after prosthetic treatment for each subject surveyed.

○The number of implants lost before prosthetic treatment was excluded from analysis.

○Data from subjects on whom confirmation is not possible by means of recall, etc., are excluded from analysis.

○Criteria for success rate are prepared in advance, including factors such as mobility and bone resorption rate.

Materials and Methods

Two types of fixtures with different surface properties were employed for this study. (Phisio Odontram Implant (POI) System, Osaka, Japan).

One of them was a POI System Finafix® made of titanium alloy Ti-6Al-4V (ELI). It is a titanium thread type implant with a surface roughness of 2.7 μm and a 135–140 nm anode-oxidized layer. The other was a POI System Finatite®, which is an HA-coated thread type implant having a 20 μm thick HA coating layer applied by flame spraying (3000℃) onto the 1 mm oxidized membrane. Its Ca/P ratio is 1.66 (Ca/P of bone = 1.67). The crystallization rate is 55%, and the coating layer is located beneath the mirror-polished layer and the 2.7 μm blast layer (Fig. 1). The criteria for the evaluation of success rate of implants were prepared by adding our original elements to the 1988 Toronto Consensus Criteria.

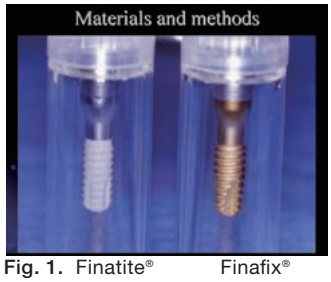

Fig. 1. Finatite® Finafix®

During the 13-year period from 1995 to 2008, 1157 pieces of HA implant were placed. Of these implants, 772 remained placed. For less than 5 years and 385 remained placed for 5 years or more. There were 128 patients with a mean age of 55 (SD = 10.1). The present study covered implants that could be followed for 5 years or more after prosthetic treatment. Six implants failed before prosthetic treatment. Hence, prosthetic treatment was performed on 379

implants. Of these implants, 57.1% were placed into the upper jaw and 42.9% into the lower jaw. The prosthetic design was most frequently the single crown, followed by fixed partial Br and full-arch Br. Removable prosthetic appliance was used rarely. Of the patients who did not participate in a follow-up appointment for the study sample, 16 showed no interest in follow-up, 3 were deceased, and 8 were unable to contact by moving out and changing clinics. Of the 128 patients who received the implants, 101 patients carrying 333 implants were included in subsequent statistical analysis. The data were analyzed statistically by Wilcoxon test using the computer program SAS9.1 (SAS Institute, Cary, NC), with 430 Ti implant (inserted during the same period) serving as the control group (Figs. 2 and 3).

Life Table Analysis Using Study Success Criteria HA-Coated Implant (at least 5yrs. post-restoration) Long Term Follow up 1995~

Years Post-restoration	No. at beginning	Failed during interval	Withdrawn during interval	Implant failure rate	Implant survival rate	Survival rate at end of period
0-1	379	1	1	0.26	99.74	99.74
1-2	377	4	16	1.08	98.92	98.65
2-3	357	1	10	0.28	99.72	98.37
3-4	346	1	7	0.29	99.71	98.09
4-5	338	2	3	0.59	99.41	97.50
5-13	333	3	11	0.92	99.08	96.61

Excluding loss before prosthetic treatment 6 cases

Fig. 2. Results of meta-analysis of HA implants (rounded to 2 decimal places)

Life Table Analysis Using Study Success Criteria Ti surface Implant (at least 5yrs. post-restoration) Long Term Follow up 1993~

Years Post-restoration	No. at beginning	Failed during interval	Withdrawn during interval	Implant failure rate	Implant survival rate	Survival rate at end of period
0-1	412	4	15	0.99	99.01	99.01
1-2	393	3	30	0.79	99.21	98.23
2-3	360	3	29	0.87	99.13	97.37
3-4	328	1	38	0.32	99.68	97.06
4-5	289	0	17	0	100	97.06
5-13	272	2	27	0.77	99.23	96.31

Excluding loss before prosthetic treatment 18 cases

Fig. 3. Results of meta-analysis of Ti implants (rounded to 2 decimal places)

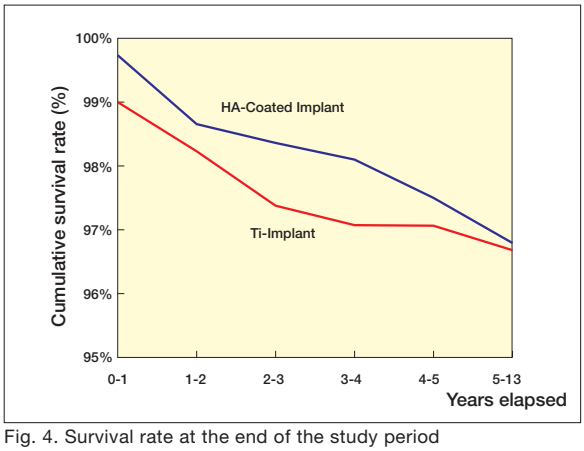

Fig. 4. Survival rate at the end of the study period

Analysis by site

	HA-coated implants (%)	Ti implants (%)
Maxilla	95.90	88.37
Mandible	97.06	98.23

Analysis by anterior /posterior

	(%)	HA-coated implants	Ti implants	Total
Maxilla	Anterior	96.97	97.06	97.00
	Posterior	95.35	82.69	92.27
Mandible	Anterior	83.33	100	93.33
	Posterior	97.69	98.13	97.93

Fig. 5. Follow up of implants kept inserted for 5 years or more after prosthetic treatment (HA–coated implants and Ti implants)

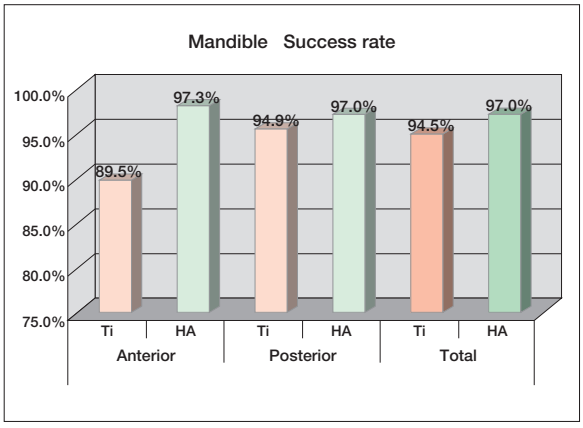

Fig. 6. Overall analysis including short follow-up cases (mandible)

Fig. 7. Overall analysis including short follow-up cases (maxilla)

Results of statistical analysis

Fig. 2 shows the results of meta-analysis of HA-coated implants. As described above, the number of implants that failed before loading was 6. When data were processed at the end of each subsequent year, the number of failed implants ranged from 1 to 4 per year, and 1–16 withdraws (drops out on research) were observed per year. The cumulative success rate for cases elapsing 5–13 years after the beginning of loading was 96.61%. A noteworthy finding from the meta-analysis of Ti implants (Fig. 3) is that 18 implants had failed before loading. If this result is combined with the fact that the level of technical error was identical to that of HA-coated implants, it seems likely that healing immediately after placement and initial integration differ between the HA surface and Ti. Further, the data on Ti implants were processed at the end of each subsequent year, revealing that the number of failed implants was 0–4 per year, 15–38 withdraws(drops out on research) were observed per year and the cumulative success rate for the cases elapsing 5–13 years after the beginning of loading was 96.31%. Fig. 4 shows a graph comparing the survival rate at the end of the follow-up period between Ti implants and HA-coated implants. Both groups depicted a similar downward curve while maintaining the difference in failure rate observed soon after prosthetic treatment. There was no significant difference in the results between the 2 groups at a significance level of 0.05. A noteworthy finding is that when the results were analyzed by site, a significant difference was noted in the upper molar implants between the 2 groups (Figs. 5 through 7).

Summarized results of statistical analysis

1) In the follow-up study of 385 HA-coated implants for 13 years, the success rate for 5–13 years was 96.61%. When analyzed for maxilla and mandible separately, the success rate was 97.06% for mandible and 95.90% for maxilla.

2) With regard to the early outcome of HA-coated implants, Wheeler[4] reported that failure began to appear several years after prosthetic treatment and that many implants failed thereafter, accompanied by peri-implantitis. In the present study, however, the success rate of HA-coated implant decreased from 98.09% (4 years after prosthetic treatment) to 97.50% (5 years after treatment), but this change during the one-year period was not statistically significant (Fig. 2), and no case followed the clinical course of failure similar to the one described above.

3) The long-term success rate did not differ significantly between HA-coated implants (96.61%) and Ti implants (96.31%). A noteworthy finding from this long-term comparison was a site-specific significant difference, i.e., significant difference in upper molar implant success rate between HA-coated implants (95.35%) and Ti implants (82.69%).

II.Classification of bone defect patterns around the failed implants

The data collected on implant failure in this study were analyzed in more detail, and the failure was divided into 3 patterns depending on radiological and clinical features: Type 1 defect (horizontal and vertical defect on X-ray is below 1 mm; symptoms such as pain and infection not observed; implant withdrawal and immediate re-placement possible), Type 2 defect (horizontal and vertical defect on X-ray over 1 mm; symptoms such as acute bone destruction and infection/pain observed rarely; implant withdrawal and immediate re-placement possible if infection is absent and initial fixation is achieved), and Type 3 defect (bone defect beyond root apex visible on X-ray, accompanied by fenestration and cleavage; often presenting symptoms such as acute bone destruction and infection/pain; re-placement immediately after withdrawal impossible).

Comparison of failure patterns

(incidence of each pattern rounded to 2 decimal places)

	Type1	Type2	Type3
HA	72.22 %	22.32 %	5.56 %
T i	73.37 %	26.32 %	5.26 %

As shown in the table above, there was no significant difference in the bone defect patterns between HA-coated implants and Ti implants. During routine clinical care, Type 1 defect, showing mobility due to disintegration, was dealt with by the removal of the fixture and surrounding tissue debridement, followed by immediate placement of a new slightly larger diameter fixture (Fig. 8). In Type 2 defect cases, implant withdrawal and immediate re-placement were possible if infection was absent and initial fixation was achieved. Type 3 defect is the severest bone defect, often accompanied by symptoms such as infection and pain, and we judged it impossible to perform implant withdrawal and immediate re-placement in such cases (Fig. 9).

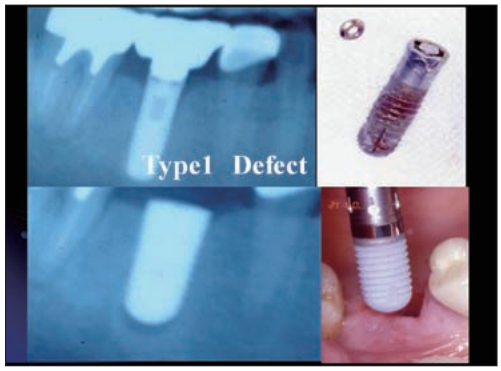

Fig. 8. If mobility due to disintegration occurred in cases free of type 1 defect and clinical symptoms such as pain and swelling were observed, the implant was removed immediately, followed by curettage and re-placement of an implant.

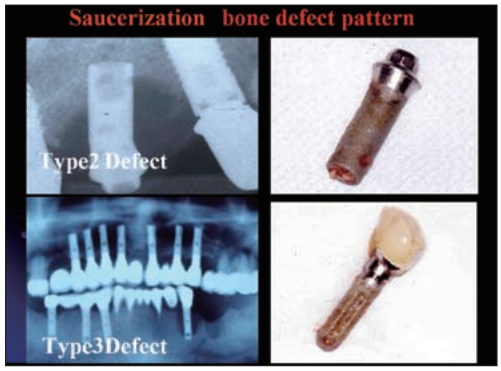

Fig. 9. Upper: A case of TPS-coated follow cylinder type implant Lower: A case of HA-coated cylinder type implant

III.Materials and methods for histological evaluation

An adult female with single crown prosthetic HA-coated implant having elapsed 2 years after loading. Because of Abutment screw trouble, the implant was removed with Trepine Bur. After obtaining the patient's consent, the removed implant was embedded and fixed for histological examination of the longitudinal and transverse sections. Like the method of processing bone biopsy samples, the removed implant was subjected to 70% ethanol fixation, staining, acetone monomer dehydration, resin embedding, and heating for polymerization. Bone and surrounding tissue were observed by staining with toluidine blue, and the tissue structure was observed under an electron microscope. This was followed by evaluation of 20 visual fields with fluorescent staining to determine the BIC rate (bone-implant contact rate) on the longitudinal section (Fig. 10).

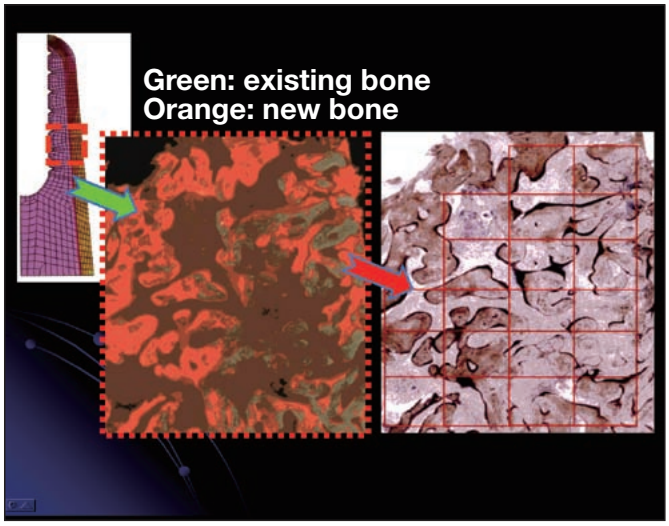

Fig. 10. Specimens fixed in 70% ethanol, stained, dehydrated with acetone monomer, embedded with resin, and heated for polymerization. The existing bone and new bone were analyzed by fluorescent staining (green: existing bone, orange: new bone). Bone marrow was observed under a light microscope (×200, 20 visual fields).

Results of histological evaluation

Around the titanium alloy, a 20 μm HA-coating layer and the surrounding 100 μm bone-like tissue were observed. When observed under light and electron microscopes (×20–300), the connection of HA coating to mature bone was visible (Fig. 11). No void or fibrous tissue was observed on the implant-bone interface, and no aberrant epithelial tissue or inflammatory cell infiltration was detected. No foreign body reaction was observed around the implant. At some sites, direct binding of osteoblasts to HA was noted.

Then, on the longitudinal section, the existing bone and new bone were examined with fluorescent staining to calculate the BIC rate (green: existing bone, orange: new bone). Measurement was performed for 20 visual fields under a light microscope (×200). BIC rate was approximately 60%. The HA-coating layer had been absorbed slightly more markedly in the direction along the crown.

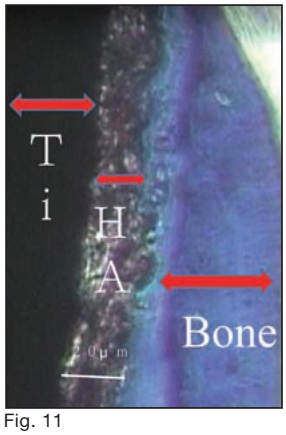

Fig. 11

Discussion

HA coating has clinical advantages (promotion of integration and effectiveness on sites with poor bone quantity or quality). However, long-term stability of HA coating has been considered doubtful. Indeed, HA coating is susceptible to the influence of biofilm, and the methods of HA coating involving a high risk (possibly affecting long-term stability) have been used in the past (Fig. 9). Clinicians should seriously review these past problems. However, despite such concerns with HA coating, the long-term failure rate for HA-coated implants that remain inserted for 5 years or more after prosthetic treatment had not increased markedly, suggesting that HA coating is unlikely to serve as a factor responsible for the failure of implants in the long-term follow-up surveys.

Attempts of enhancing bone binding to implant surface can be roughly divided into the coating method (HA, TPS, Sintered, Oxides) and the un-coating method (SLA, Osseotite, TiUnite). As compared to first-generation implants, these second-generation implants have an overwhelmingly higher potential of stimulating the binding of osteoblasts and making the implant stronger. Furthermore, the materials used for second-generation implants are superior also in terms of surface adhesiveness (due to the coarse surface. Furthermore, second-generation implants are higher in terms of cell-differentiating potential in vitro as well as in terms of contact rate with surrounding bone, binding power, and fixative power in vivo[5-10]. Buser et al.[11] verified the relationship between implants with coarse surface and the implant-bone contact rate in 1991. According to their report, the implant-bone contact rate was 20%–25% for implants with sandblast and acid pickled surface, 30%–40% for implants with TPS coating (sand-blast large grit and acid-etched and titanium plasma-sprayed), 50%–60% for SLA (sand-blast large grit and acid textured), and 60%–70% for HA-coated implants. Many other reports providing similar results have been published.

Recently, a histological study was reported, demonstrating that an HA-coated fixture removed after a long time (15 years) after placement showed almost complete absorption of the HA coating layer and noninvasive direct contact between Ti surface and bone as a result of long-term repeated remodeling[12] (Fig. 12).

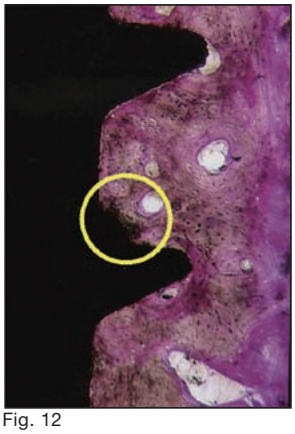

Fig. 12

THD (Bausch & Lomb) at 15 years after placement. Bone/implant contact rate is 77.6 ± 5.1%, but HA has been absorbed completely and bone/HA contact rate is 5.1 ± 2.3%.
(Reproduced with modifications from The International Journal of PRD Vol.17, No.2, 2009[12])

Some investigators reported that the infected HA-coated fixture is destroyed by the surrounding tissue[8], while other investigators reported that Haversian canal was observed in the vicinity of implant surface and that the normal bone remodeling correlated with HA absorption[12]. In the latter report, the HA isolated from the HA-coated fixture showed no sign of foreign-body reaction, and it was shown that ossification occurred in the HA-absorbed area, similar to the finding reported by Hardy and Frayssinet[13].

To date, however, very few reports have been available concerning the relationship with soft tissue. In this connection, Block et al.[14] published a noteworthy report, in which he suggested that when HA-coated mandibular implants were followed for 10 years, the failure rate was only 2.9% for patients having keratinized gingiva, but as high as 29.5% for patients free of keratinized gingiva, accompanied by poor cleaning status in the latter group. A skill used to avoid the exposure of implant's HA-coating layer into the oral cavity is to arrange the polished plane (called "crest module") or the un-coating later on the side of the coating layer facing the crown. In addition, there is a report demonstrating that the HA coating layer can adequately resist changes in pH and remains stable even when it is exposed into the oral cavity. The implant body has a macroscopic design, whereas the crest module is often smoother to impair plaque retention if crestal bone loss ocure. The apical dimension of the crest module varies greatly from one system to another (0,5mm to 5mm).

Because special environments (mucosa-perforating area) are involved during dental management, minute processing of this part by un-coating to elevate the potential of integration will work favorably. It is desirable to introduce the alkali heating technique (clinically introduced in the field of hip-joint management: AHFIX®)[15], outcome of technological innovation at the molecular level such as nano-size HA particle coated surface (NanoTite®) and macro-designs (platform switch, etc.) facilitating the stabilization of the quality and quantity of this area and resistance to bone resorption during loading.

As shown in the analysis conducted during this study, HA coating of the surface of the implant within the bone can lead to high success rate in the upper posterior region and allow the acceleration of integration and consolidation of the implant inserted into relatively soft bone. This coating also appears to be beneficial when the implant is placed into the socket after tooth extraction or the regenerated bone (sinus lift, etc).

Assuming that the cause for the failure of HA-coated implants was similar to that for the failure of Ti implant in the cases covered in this study, how does the failure begin? Sauce-shaped early bone resorption at the neck of implant can cause a condition akin to that observed in the periodontal pocket. Regardless of the shape of implants, many reports from statistical analysis revealed that the amount of bone resorption at the tooth neck occurred rapidly during the first year[16-19]. According to the measurement performed with reference to the first screw thread by Adell et al.[17], bone resorption at the bone apex was large, particularly during the first year [mean 1.5 (3.3) mm], and the resorption in subsequent years was smaller (0.05–0.13 mm/year). Misch[20] studied the cause for early bone resorption at the bone apex, citing the hypotheses given below.

① Periosteal reflection hypothesis
② Implant osteotomy hypothesis
③ Autoimmune response of host hypothesis (associated with bacteria)
④ Biological width hypothesis
⑤ Mechanical stress factors hypothesis

Misch reported that hypotheses ① through ③ cannot explain the cause of resorption. Hypothesis ④ is valid to some extent but cannot fully explain the cause. He supported the mechanical element ⑤ most strongly.

Indeed, bone can change in response to stress. Frost[21] divided the osseous tissue associated with mechanical adaptation to pre-fracture strain force into the following 4 window: (a)Acute disuse atrophy window, (b) Adapted window, (c) Mild overloading window (stimulating calcification), and (d) pathologic overload (fatigue fracture and bone resorption). Furthermore, the changes of bone in response to stress can vary depending on the maturity level, hardness, and the amount of bone exposed to stress; further, it appears that the bone around the implant is exposed to risk during the first year after prosthetic treatment and that the risk becomes lower in the second and subsequent years because of further bone maturation and stabilization of bone hardness and amount.

According to the recent mechanical studies on dental implants, the resistance of bone is the highest to compressive force (±0%) and lower to tensile force (–30%) and shear stress (–65%). With many implants, the shear stress arising from occlusion is converted at the first screw thread into compressive force or tensile force, and bone resorption is prevented by 40%–70% elevation in resistance to such forces. Even a slight (0.25 mm) increase in implant diameter leads to as much as 5%–10% increase in surface area. Therefore, when mechanical elements are taken into account during clinical planning, the implant diameter is more important than the implant length. Wonejae Yu et al.[22] conducted a mechanical study of the stress loading area at varying implant diameters and bone apex widths, using the finite element method. In that study, a saucer-shaped stress loaded area was observed at the bone apex corresponding to the implant neck, and it was quite akin to the form of initial bone resorption. Wide-body implants with a larger diameter are mechanically more useful than elongated standard body implants. However, they involve a risk for reducing the bone width (biological width). Tissue with both small width and not supported by bone marrow is likely to fail during the acute or subacute stages. Among others, cortical bone lacking marrow cavity is poor in regenerative potentials and is likely to be resorbed. Furthermore, since biological width encompasses a horizontal dimension as well, the author thinks that bone tissue possessing marrow cavity with a regenerative potential needs to have at least 2 mm thickness of bone/periosteum (Fig. 13 and 14).

Assuming that the cause for the failure of HA-coated implants is identical to that for the failure of Ti implants, the failures observed during this study may be attributed to the concentration of stress on the premature bone or thin cortical bone at the apex facing the implant neck, resulting in the beginning of bone resorption and creation of a condition akin to periodontal pocket, and excluding the failures attributable to pre-loading factors (surgery, fixture surface properties, patient's factors). If this view is valid, the implant diameter and the design of its neck will be important. Wide-body implants should be inserted into a location within the existing tissue where post-healing bone resorption and adequate width of regeneration (biological width) are assured. If such a biological width is absent, early bone resorption may occur, possibly leading to the failure of the implant.

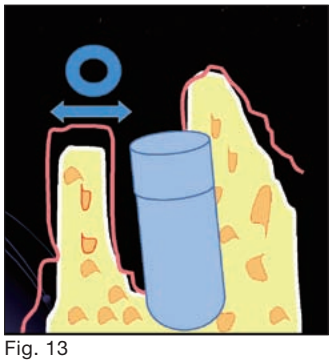
Fig. 13

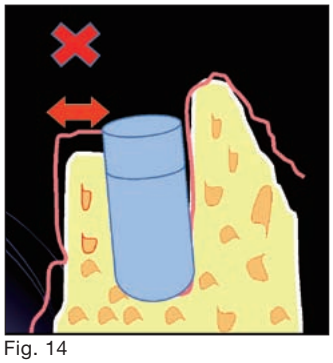
Fig. 14

Conclusion

The results of the 13-year evaluation of second-generation thread type HA-coated implants in the present study were clinically satisfactory. A noteworthy finding from this long-term comparison was a site-specific significant difference, i.e., significant difference in upper anterior implant success rate between HA-coated implants and Ti implants. The cause of failure, as analyzed from the patterns of radiological bone defects and clinical symptoms, appears to differ little between these implants and Ti implants. Some requirements revealed in this study seem to be useful in elevating the predictability of integration.

Acknowledgments: The author is indebted to Professor Kanichi Nakagawa (Tokyo Dental College) and Professor Ichiro Nishimura (UCLA) for their advice about basic and clinical implantology for a long period of time. Part of this paper was presented at the 38th meeting of the Japanese Society of Oral Implantology (2008), The First ICOI Japan Advanced implant symposium (2009), and the JMM Colloquium (2009).

References

1)BIESBROCK, A.R.and EDGERTON, M. :Evaluation of the clinical predictability of hydroxyapatite-coated endosseous dental implants: A review of the literature ;Int. J ,Oral Maxillofac. implants,10:712-720,1995.

2)ALBREKTSSON, T.and SENNERBY, L. :State of the art in oral implants ;J. Clin. Periodontal,18:474-481,1991.

3)LOZADA, J.L.and JAMES, R.A.and BOSKOVIC, M.: HA-coated implants. Warranted or not? ;Compend Contin Educ. Dent., 15(suppl):539-543,1993.

4)WHEELER, S.,L. :Eight-year clinical retrospectve study of titanium plasma-sprayed and hydroxyapatite-coated cylinder implants ; Int .J. Oral Maxillofac. Implants, 11:340-350,1996.

5)MASUDA T, YLIHEIKKILA PK, FELTON DA, Cooper LF：. Generalizations regarding the process and phenomenon of osseointegration. Part. In vivo studies. ; Int .J. Oral Maxillofac. Implants ,13:17-29,1998.

6)TAKEUCHI K, SARUWATARI L, NAKAMURA HK, YANG JM, OGAWA T：. Enhancedintrinsic biomechanical properties of osteoblastic mineralized tissue on roughened titanium surface；J. Biomed Master Res A, 72A:296-305 ,2005.

7)BUTZ F,AITA H, TAKEUCHI K, OGAWA T. : Enhanced mineralized tissue adhesion to titanium over polystyrene assessed by the nanoscratch test. ; J. Biomed Mater Res A, 74: 164-170, 2005.

8)BUTZ F, AITA H, WANG CJ, OGAWA T. ：Harder and stiffer bone osseointegrated to roughened itanium；J. Dent Res ; 85: 560-565, 2006.

9)OGAWA T, NISHIMURA I. : Different bone integration profiles of turned and acidetched implants associated with modulated expression of extracellular matrix genes；. Int J. Oral Maxillofac Implants, 18:200-210, 2003.

10)OGAWA T, OZAWA S, SHIN JH, RYU KH, SUKOTJO C, YANG JM, et al. : Biomechanical evaluation of osseous implants having different surface topographies in rats；. J. Dent Res, 79:1857-1863, 2000.

11)BUSER, D., SCHENK, RK., STEIMEMANN, S., FIORELLINI, JP.,FOX, CH. and STICH, H. : Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs ;Biomed. Meter. Res., 25(7) ：889-902,1991.

12)GIOVANNA LEZZI ,SERGIO ORLANDI,GABRIELE PECOA, ADRIANO PIATTELLI.: "Histologic and Histomorphometric Evaluation of The Bone Response Around a Hydroxyapatite=Coated Implant Retrieved After 15 years" The International Journal of Periodontics&Restorative Dentistry Volume 17,Number2,2009

13)FRAYSSINET P, HARDY D, HANKER JS, GIAMMARA BL. Natural history of bone response to hydroxyapatite-coated hip prostheses implanted in humans.Cell Mater 1995;5:125-138

14)BLOCK, MS., GARDINER, D., KENT J.,MISIEH D., et. al, :Hydroxyapatite-coated Cylindrical Implants in the posterior, Mandible 10-year Observations ; Int.J.Oral Maxillofac.Implants,11:626-633,1996.

15)NISHIGUCHI, S., NAKAMURA, T., KOBAYASHI, M., KIM, H., MIYAJI, F. and KOKUBO, T. :The effect of heat treatment on bone-bonding ability of alkali-treated titanium; Biomaterials 20:491-500 ,1999.

16)LINKOW LI: Statistical analyses of 173 patients, J Oral Implantol 4：540-562, 1974.

17）ADELL R, LEKHOLM U, ROCKLER B, et al: A 15 year study of osseointegreted implants in the treatment of the edentulous jaw,Int j Oral Maxillofac surg 10:387-416, 1981.

18)ADELL R, LEKHOLM U, ROCKLER B, et al: Margnal tissue reactions at osseointegreted titanium fixtures（1）：a 3 year longitudinal prospective study , Int j Oral Maxillofac surg 15:39-52, 1996.

19)TONETTI MS, SCHMID J: Patheogenesis of implant failures, Periodontology 2000 4:127-138,1994.

20)MISCH CARL E.: Dental Implant Prosthetics：72-82. Mosby, Inc. 2005

21)FROST HM：Mechanical adaptation :Frost's mechanostat theory. In Martin RB, Burr DB, editors: structure, function, and adaptation compact bone, New York,1989,Raven Press

22)WONEJAE YU, YOON-JE JANG, HEE-MOON KYUNG Combined Influence of Implant Diameter and Alveolar Ridge Width on Crestal Bone Stress: A Quantitative JOMI Volume 24,Number1,2009

for the patient

JAPAN MEDICAL MATERIALS

Japan Medical Materials Corporation

Head Office
Uemura Nissei Bldg. 9F 3-3-31 Miyahara, Yodogawa-ku,
Osaka 532-0003 Japan
Tel:+81-6-6350-1534 Fax:+81-6-6350-1038

Shiga Gamo Plant
10-1 Kawai-cho, Higashiomi-shi,
Shiga 529-1595 Japan
Tel:+81-748-55-4417 Fax:+81-748-55-4402

2010.1