CLINICAL ANALYSIS

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Effect of loading time on marginal bone loss around hydroxyapatite-coated implants

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Abstract (J Korean Assoc Oral Maxillofac Surg 2013;39:161-167)

Objectives: The objective of this study is compare the rate of marginal bone resorption around hydroxyapatite-coated implants given different loading times in order to evaluate their stability.

Materials and Methods: The study was conducted retrospectively for one year, targeting 41 patients whose treatment areas were the posterior maxilla and the mandible. Osstem TS III HA (Osstem Implant Co., Busan, Korea) and Zimmer TSV-HA (Zimmer Dental, Carlsbad, CA, USA), which employ the new hydroxyapatite coating technique, were used. The patients were divided into two groups - immediate and delayed loading - and the bone level at the time of loading commencement and after one year of loading was measured using periapical radiography. Differences between the groups were evaluated using Mann-Whitney (α=0.05).

Results: For all patients as a single group, the survival rate of the implants was 100%, and the mean marginal bone loss was 0.26±0.59 mm. In comparison of the differences by loading, mean marginal bone loss of 0.32±0.69 mm was recorded for the immediate loading group whereas the delayed loading group had mean marginal bone loss of 0.16±0.42 mm. However, the difference was not significant (P>0.05).

Conclusion: Within the limited observation period of one year, predictable survival rates can be expected when using immediately loaded hydroxyapatite-coated implants.

Key words: Loading, Bone loss

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I. Introduction

Osseointegration is the most important factor in successful implant treatment. In the early stage, machined surface implants using pure titanium were reported to have achieved successful osseointegration, but there were limitations in case of low volume and quality of bony tissue[1]. In addressing these issues, various surface-treated implants were developed and sold to facilitate osseointegration and promote initial healing. Among them, hydroxyapatite (HA)-coated implants made by applying HA on the surface using plasma spray to generate depression, undercut, and porosity were introduced in the mid-1980s to increase osteogenesis and facilitate osseointegration[2]; they were actively used in the 1990s. Note, however, that most products were terminated because many researchers reported high failure rates. Some researchers claimed that, from the long-term perspective, HA-coated implants can lose osseointegration because, if the coated surface is detached from the fixture or resorbed, the implant and bone are separated; thus becoming dynamically unstable.

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Even with satisfactory early osseointegration, the HA-coating is easily contaminated, and this results in its resorption and subsequent failure of the implant[3]. Nonetheless, some researchers report that advancements in HA-coating technology have resolved these problems and produced long-term stable clinical results. Insufficient stability resulting from HA-coating desquamation and irregular coating thickness has been addressed with technological advancements such as ion plating[4] and ion sputtering[5], thermal decomposition method[6], and biomimetic process. Another viable option is the more recently developed thermally induced liquid-phase deposition method[7].

Another important factor in successful osseointegration following implant placement is loading. Currently, it is regarded as principle wherein a certain healing period is assigned without loading. According to Brånemark et al.[8], premature loading after implant placement can generate fibrous tissue on the bone-implant interface rather than bone deposition; thus, insufficient healing period increases the possibility of early or delayed mobility of the implant. The minimum healing period suggested by Brånemark in 1977, based on 10 years' clinical experience, was 3 months for the mandibular implant and 5-6 months for the maxillary one[8]. Albrektsson[9] stated that the most important period is the first month following implant placement. Excessive loading during this period can damage the balance between bone generation and bone resorption and result in fibrous connective tissue that interferes with osseointegration. Note, however, that the traditional healing period suggested by Brånemark may not be suitable today because the Brånemark research was based only on machined surface implant; it did not consider the implant design, surface treatment, surgical method, and biomechanical prosthesis[10]. Recent research on the stability of immediate and early loading reported success rates of 88-100%, suggesting that the healing period after treatment will continue to decrease[1,11,12].

Marginal bone height is an important factor in the implant's functional and aesthetic success, and maintaining the proper height of marginal bone is a precondition for the implant's long-term, satisfactory use. Marginal bone resorption in the bone-implant interface interferes with the stability of surrounding tissues and causes periimplantitis or mobility of the implant. Vercruyssen and Quirynen[13] reported that, in their long-term research, smoking, guided bone regeneration, dehiscence defect, and bony tissue are closely related to the height of marginal bone around the implant. Based on the researchers' reports, i.e., failure of a loading implant most frequently occurs within one year of functioning[14], this study measured the amount of resorption after one year of loading.

To compare the stability of HA-coated implants with different loading initiation times, two different implants that secured thinner and more even thickness of HA coating and increased crystallization rate were placed on patients: Osstem TS III HA (Osstem Implant Co., Busan, Korea) and Zimmer TSV-HA (Zimmer Dental, Carlsbad, CA, USA). After applying immediate and delayed loading based on the definition of Cochran et al.[15], implant survival rate was measured according to criteria established by Buser et al.[16] and Cochran et al.[17] After one year of loading, the resorption amount of crestal bone was evaluated retrospectively.

II. Materials and Methods

1. Materials and subjects

This study was conducted by the Section of Dentistry at Seoul National University Bundang Hospital, following approval by the institutional review board (approval No. B-1012-117-105). We have read the Helsinki Declaration and have followed the guidelines in this investigation. The 1-year retrospective study involved a total of 41 patients (74 implants, 22 males and 19 females with mean age of 53.10±10.70) who had 1 or 2 implants placed consecutively in their posterior maxilla or mandible and immediate or delayed loading between September 2010 and April 2011. Osstem TS III HA was implanted in 17 patients (33 implants), and Zimmer TSV-HA (41 implants), in 24 patients.(Table 1) Patient selection criteria for implant placement were as follows: 1) patients older than 18 years whose jaw growth was finished; 2) patients with posterior teeth loss and available alveolar bone height of more than 6 mm; 3) patients with adequate mesiodistal and horizontal available bones; and 4) patients with antagonistic tooth of placed implant. The following were the criteria for exclusion: 1) pregnant women; 2) patients who had a heart attack only recently; 3) patients with uncontrollable systemic disease; 4) patients with hemorrhagic disease or disease requiring the administration of anticoagulant; 5) patients with, or suspected of having, a psychological disease; 6) patients who were scheduled to undergo tooth extraction within 2 months in the placement area and patients with severe periodontal disease in the surrounding teeth; 7) patients with grade D4 bony tissue; 8) patients who need extensive bone graft; and 9) patients for which placing an implant is difficult (patients with severe oral habit such as bruxism).

Table 1. Descriptive data for study groups

Variable	Value
Sex	
Male	22
Female	19
Total	41
Age (yr)	
Male	51.41±11.30
Female	55.05±9.91
Mean	53.10±10.70
Type of loading	
Immediate loading	42
Delayed loading	32
Total	74
Mean period between 1st surgery and initial loading (d)	
Immediate loading	1.81±0.40
Delayed loading	149.30±48.58
Method of installation	
1-Stage method	51
2-Stage method	23
Total	74
Type of implant system	
Osstem TS III HA	33
Zimmer TSV-HA	41
Total	74
Area	
Maxilla	41
Mandible	33
Total	74
Implant diameter (mm)	
3.70	3
4.00	4
4.10	4
4.50	6
4.70	32
5.00	23
6.00	2
Total	74
Implant length (mm)	
7.0	1
8.0	2
8.5	2
10.0	59
11.5	9
13.0	1
Total	74

Values are presented as number or mean±standard deviation.
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2. Implant placement and loading

In this study, all surgeries and prosthesis treatments were performed by 1 surgeon and 1 prosthodontist. Implants were placed according to each manufacturer's guidelines, and bone graft was performed when a small defect around the implant was noted. If the residual bone in the maxillary posterior teeth was 6-10 mm, sinus membrane elevation and bone graft were performed using a crestal approach, and implantation was done at the same time. Based on the period from implant placement to loading by prosthesis, 42 implants were categorized as immediate loading (IL) group, and 32 implants, as delayed loading (DL) group. The IL group was then subdivided into 18 Osstem TS III HA implants and 24 Zimmer TSV-HA implants based on the implant system. The DL group was also subdivided into 15 Osstem TS III HA implants and 17 Zimmer TSV-HA implants.(Table 2)

Table 2. Distribution of cases by loading period and implant system

Loading type	Implant system	Number of implant
Immediate loading	Osstem	18
	Zimmer	24
	Total	42
Delayed loading	Osstem	15
	Zimmer	17
	Total	32

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Based on the definition of Ioannidou and Doufexi[12], the IL group had a temporary crown restored within 48 hours as well as occlusion with the opposite tooth (after 1.81±0.40 days on the average); final restoration was done 3-6 months after placement (6 months for the maxilla and 3 months for the mandible) after confirming osseointegration. The DL group had healing period of 2.8-7.9 months (5.5 months for the maxilla and 3.0 months for the mandible on the average) after placement, with final restoration and occlusion with the opposite tooth. For the temporary crown restoration of the IL group, occlusion space as wide as 1 Accufilm (Parkell, Farmingdale, NY, USA) was applied when biting slightly; occlusal contact was unavailable for lateral movement. In the final restoration of the successful IL group and DL group, occlusion space as wide as 1 Shimstock (Kocodental, Bucheon, Korea) was created when biting slightly.

3. Measurement of implant survival rate and bone resorption

Both the IL group and DL group visited our hospital on the initial day of loading and 1 year later for periapical radiography and to evaluate the clinical symptoms, mobility of implant, radiolucency around the implant, and status of soft tissue to determine the implants' survival rate. Using the criteria suggested by Buser et al.[16] and Cochran et al.[17], the implant survival rate was evaluated: a. no clinical implant mobility; b. no pain or neural problem; c. either infection around the implant is not consistent, or it has not recurred; d. neither radiolucency around the implant nor rapid bone loss.

To measure and compare marginal bone resorption around the implant, digital periapical radiography was taken vertically from the longitudinal axis using the parallel cone technique. Marginal bone level was measured on the mesial and distal sides of the implant, with the mean of two values regarded as representative value. Considering the fact that the distance between the threads of fixture (thread pitch) was 0.8 mm (4.5 mm in diameter) or 0.9 mm (5 mm in diameter) for TS III HA and 0.6 mm for TSV, the distance from the implant platform to the first bone-implant contact (BIC) in radiographs was measured and calculated by enlargement ratio. Marginal bone loss was calculated as the difference between the values taken on the initial day of loading and values taken at 1-year prosthetic loading. Because of the submerged machined collar (1 mm band) of TSV, the placement depth of machined-to-resorbable blast media junction during surgery had to be compensated when bone loss was measured at 1-year follow-up. This depth was subtracted from the measurement to adjust the actual bone loss of the textured surface. The difference was measured by setting 2 dots on the radiograph using IMPAX (Agfa Corp., Mortsel, Belgium) program to measure the distance. Measurement was conducted by one dentist who did not participate in the implant treatment.

4. Statistical analysis

After placing the HA-coated implants, data was examined to determine whether there is significant relationship between initial loading time, initial loading time by implant system, initial loading time by maxilla and mandible, and change of crestal bone's height after 1 year of loading using Mann-Whitney (α=0.05) of IBM SPSS Statistics ver. 20.0.0 (IBM Co., Armonk, NY, USA).

III. Results

Implant survival rate after 1 year of loading was 100%, and mean bone loss of all test groups was 0.26±0.59 mm. For the comparison based on loading time, mean bone loss of the IL group was 0.32±0.69 mm, and that of the DL group was 0.16 ±0.42 mm, but the difference was not statistically significant (*P*=0.260).(Table 3) Regarding bone loss of the IL group and delayed group receiving the Osstem TS III HA, bone loss was 0.52±1.00 mm and 0.11±0.20 mm, respectively, but the difference was not statistically significant (*P*=0.556).(Table 4) For patients receiving the Zimmer TSV-HA, bone loss of the IL group and DL group was 0.17±0.21 mm and 0.17± 0.21 mm, respectively, but the difference was not statistically significant (*P*=0.338).(Table 5) In comparing the bone loss of IL group and DL group in the maxilla and the mandible, bone loss in the maxilla was 0.41±0.82 mm and 0.10±0.16 mm in the IL group and DL group, respectively, but the difference was not statistically significant (*P*=0.526).(Table 6) Likewise, in the mandible, bone loss of the IL group was 0.27 ±0.61 mm, and that of the DL group was 0.39±0.84 mm; the difference was not statistically significant (*P*=0.620).(Table 7)

Table 3. Mean crestal bone resorption by loading type (at 12 months' loading)

Loading type	Number of implant	Bone loss (mm), mean±standard deviation	*P*-value*
Immediate loading	42	0.32±0.69	0.260
Delayed loading	32	0.16±0.42	

**P*-values were calculated with Mann-Whitney (α=0.05).
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Table 4. Mean crestal bone resorption by loading type in Osstem TS III HA (at 12 months' loading)

Loading type	Number of implant	Bone loss (mm), mean±standard deviation	*P*-value*
Immediate loading	18	0.52±1.00	0.556
Delayed loading	15	0.11±0.20	

**P*-values were calculated with Mann-Whitney (α=0.05).
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Table 5. Mean crestal bone resorption by loading type in Zimmer TSV-HA (at 12 months' loading)

Loading type	Number of implant	Bone loss (mm), mean±standard deviation	*P*-value*
Immediate loading	24	0.17±0.21	0.338
Delayed loading	17	0.21±0.56	

**P*-values were calculated with Mann-Whitney (α=0.05).
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Table 6. Mean crestal bone resorption by loading type in the maxilla (at 12 months' loading)

Loading type	Number of implant	Bone loss (mm), mean±standard deviation	*P*-value*
Immediate loading	16	0.41±0.82	0.526
Delayed loading	25	0.10±0.16	

**P*-values were calculated with Mann-Whitney (α=0.05).
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Table 7. Mean crestal bone resorption by loading type in the mandible (at 12 months' loading)

Loading type	Number of implant	Bone loss (mm), mean±standard deviation	*P*-value*
Immediate loading	26	0.27±0.61	0.620
Delayed loading	7	0.39±0.84	

*P-values were calculated with Mann-Whitney (α=0.05).
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IV. Discussion

HA-coated implants were introduced in the 1990s and were found to facilitate the adhesion and proliferation of osteoblasts with good coherence of serum protein and growth factors, perform well on poor-quality bony tissue by significantly increasing osseointegration between implant and bony tissue, and allow performing early loading by shortening the osseointegration period[18-20]. Note, however, that the coating quality and thickness varied by manufacturer, and the coating was occasionally removed during implantation. Thus, a divided HA was found to have risk of impairing osseointegration and initiating an inflammatory response[3,21].

After the introduction of ion plating and ion sputtering, these problems were resolved, and the success rate has steadily increased along with advancements in HA-coated technology[7]. In 2005, Trisi et al.[18] collected samples from the clinical specimen of 10-year-old HA-coated implants and, after histological analysis, reported loss of less than 25% for the HA-coating surface and BIC rate of 78.48%. In other words, for patients receiving proper prosthetic treatment and adequate maintenance, persistent HA coating and long-term survival were possible. Many other studies also noted progress in HA-coated implants and good clinical results[18-20]. HAPTITE (Dentis Co., Ltd., Daegu, Korea) claimed to have resolved uneven coating and desquamation problems by reducing coating thickness to 2 μm using an ultra-thin coating technique applied in vacuum at room temperature[22]. The Zimmer TSV-HA used in this study recorded a 97% success rate because it increased the HA crystallization rate to 97% with the application of plasma coating over HA and special MP-1 process using compressed hydration heat treatment[23]. Crystallization rate is an important factor in HA-coated implants because a non-crystallized HA-coated surface may melt, break, or disintegrate and cause the implant to fail. In this study, the coating thickness of Osstem TS III HA was 20-70 μm, and that of Zimmer TSV-HA was 20-150 μm. In both products, thermal plasma coating was applied. In x-ray diffraction (XRD) and energy dispersive spectrometer (EDS) analysis, the Ca/P ratio of Osstem TS III HA was 1.69, and that of Zimmer TSV-HA was 1.65. The crystallization level of Osstem TS III HA was 98%, and that of Zimmer TSV-HA was 96.3±0.6. In ISO/TC106, HA implants must have crystallization rate of more than 62%. Considering the fact that the crystallization rate of the Steri-Oss implant (Nobel Biocare AB, Göteborg, Sweden) is 73.3%, both products used in this study have high crystallization rates.

For successful osseointegration under immediate loading following implantation, various tests and research have been conducted, and their results have been reported. In an animal test that compared a function group and a non-function group by applying a crown immediately after implantation, the microscopic examination revealed a higher rate of osseointegration in the function group. In addition, some studies found that successful osseointegration relies on loading, dental hygiene, condition of bony tissue, surgical technique, and prosthesis; thus, if the bony tissue at the implant site is healthy, tissues are subjected to minimal damage during the surgical process, and prosthesis restoration is performed carefully, osseointegration within 2 weeks is possible with early functional loading[24]. According to some studies, the success rate and survival rate under protocols calling for early loading and delayed loading following normal healing period do not differ greatly, but implant failure is greatly affected by the patient's overall physical condition, local factors such as poor oral hygiene, and unsuitable bony tissue at the implantation site[25,26]. Based on this study's results, even when applying immediate loading to HA-coated implants, the survival and bone resorption rates are not significantly different when applying delayed loading after a normal healing period.

Loading was reported not to cause independently the generation of fibrous tissue membrane, but the amount of micromotion at the bone-implant interface was more relevant. Primary stability is the most important consideration in applying immediate loading[27]. Calandriello and Tomatis[27] reported that micromotion of more than 100 μm retards healing at the bone-implant surface, whereas Szmukler-Moncler et al.[10] claimed that micromotion of more than 150 μm causes the generation of fibrous tissue membrane rather than bone deposition. Therefore, reducing micromotion and increasing the success rate with immediate loading require using an implant that has been designed for easy placement and less mobility to secure primary stability[10,27].

In both groups, average alveolar bone resorption rates under different loading times were within 0.24±0.59 mm; this was lower than the results of previously published research. According to Schincaglia et al.[28], the average bone resorption rate after 1 year of loading in mandibular single implant restoration was 1.20±0.55 mm in the IL group and 0.77±0.38 mm in the DL group. Recently, Elsyad et al.[29] reported a rate of 0.91±0.63 mm in the IL group and 0.51±0.39 in the DL group. For a two-piece implant, bone resorption rate of 1.5-2.0 mm from the 2nd surgery to 1 year of loading is regarded as normal[30,31]. In 1994, Albrektsson and colleagues[32,33] stressed that a successful implant should have less than 1.5 mm bone resorption during the first year of prosthetic treatment and subsequent annual bone resorption rate of less than 0.2 mm. Therefore, the bone resorption rate of both groups in this study is believed to be low due to the successful early stability of the HA-coated implant, skilled surgical technique, and highly motivated patients.

This research is limited because it is neither a retrospective study nor based on a selected test group and a control group. Initial stability following implantation was not measured in all cases using Ostell Mentor (Integration Diagnostics AB, Göteborg, Sweden) or others; neither were bone resorption rates by type of prosthesis compared because we reviewed medical records and radiographs of patients who had previously received implant treatment. Another limitation of this study was its insufficient control of statistical data because each patient received a different number of implants; the location of implant placement and its length and diameter also differed. The results of this study demonstrated no significant difference, but this may be due to a number of factors in this study design. For one, the use of two different implant brands increases the difficulties in interpreting the results properly. The different implants not only had different coating properties but also different thread design and different diameters, which may influence implant stability during the healing period.

Long-term follow up after 1 year of observation is necessary, and future research with prospective study should be undertaken with only 1 implant system by strictly controlling patient age, location and number of implant placements, initial stability of implant, and follow-up surgical treatment.

V. Conclusion

In this retrospective research, HA-coated implant placed in the maxillary and mandibular posterior areas recorded short-term clinical success regardless of the loading time; the amount of marginal bone resorption also met the criteria for successful implantation. Mean bone loss after 1 year of loading was not significantly different between the IL group and the DL group; neither was the difference in bone resorption rates statistically significant between the two groups by type of implant system and by dental location.

The limitations of this study include not only the study period but also other variables such as surgeon's bias, different brands of implant, etc. Even with the limited study period of one year, however, this study suggests that HA-coated implants can secure a high success rate under immediate loading.

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