Effects of thread depth in the neck area on peri-implant hard and soft tissues: an animal study

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ABSTRACT

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The aim of this animal study was to use resonance frequency analysis to examine the effects of thread depth on peri-implant tissues in terms of bone-implant contact (BIC), bone-implant volume (BIV), and hard- and soft-tissue dimensions.

Five beagle dogs received experimental intra-mandibular implants 3 months after removal of their premolars and first molars (P2, P3, P4, and M1). Two different types of implants were installed in each animal: deep threaded (DT) and shallow threaded (ST). Resonance frequency testing were performed on the day of implantation as well as 4 weeks and 8 weeks after implantation. Intraoral radiography, micro-computed tomography (μCT), and histomorphometry were used to evaluate peri-implant tissues 4 weeks and 8 weeks after implantation.

There were no significant differences in resonance frequency test results between the two groups. Although radiographic analysis showed no group differences, μCT (p = 0.01) and histomorphometry (p = 0.003) revealed that the DT group had significantly lower BIC values than the ST group at 4 weeks. However, by 8 weeks, the BIC values of the two groups did not differ significantly. No significant differences in BIV or soft-tissue height were observed between the two groups at either time point.

After 8 weeks of healing, peri-implant hard and soft tissue parameters in the implant neck area do not differ significantly between dogs given deep threaded versus shallow threaded dental implants.

Key words: animal experiments, bone implant interactions, CT imaging

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I. INTRODUCTION

Implant design modification for improvement of osseointegration can be approached on a micro-design or a macro-design level. Micro-design modification includes alterations to implant materials, surface morphology, and surface coating. Macro-design modification includes alterations to fixture body shape and thread design, with changes to elements such as the face angle and the geometry, pitch, depth (height), thickness (width), and helix angle of the threading(Geng et al., 2004; Geng et al., 2004).

In the realm of macro-design factors, thread depth has been a common site of fixture configuration modification. Shallower thread depth facilitates the surgical placement of implants into dense bone and reduces the necessity for bone tapping prior to implant insertion. Ease of surgical insertion is a primary factor affecting implant surgeons' choice of implant type. In this regard, implants with fewer threads and shallower thread depths are often preferred, because both conditions facilitate implant insertion(Misch, 2007). However, these advantages could turn into disadvantages after the placement of implants. These conditions, while favoring implant insertion, reduce the functional surface area and may increase the risk of occlusal overload at the bone-implant interface. Provided that all other variables are consistent, deeper threads provide greater implant surface contact area. Consequently, deeper threads may be clinically advantageous, especially in regions with relatively soft bone and high occlusal loading, because they provide greater functional surface area with surrounding bone(Misch, 2007).

In a previous animal study(C. Marin et al., 2010) evaluating the optimal implant healing chamber configuration, significantly lower bone-to-implant contact (BIC) values were obtained for healing chamber configurations formed by implants with deep threads. Additionally, using three-dimensional finite-element analysis (3D FEA) of various thread configurations, a previous study (L. Kong *et al*, 2008). evaluated thread depth and width to identify the optimal thread configuration for minimal stress peaks. Although the effects of thread depth in a jaw bone model have been analyzed by 3D FEA, no *in vivo* studies have examined this issue in animal models or human patients. Implant systems with improved surface coating are now commercially available in both deep and shallow thread depth, enabling differing thread depth to be compared across otherwise similar implants. The aim of this animal study was to use resonance frequency analysis to examine the effects of thread depth on peri-implant tissues in terms of BIC as well as hard- and soft-tissue dimensions.

1. Material and methods

1) Implants

Two implant types were used in this study (Figure 1): a deep-threaded implant(Anyridge Wide, Megagen, Seoul, Korea) (DT) and a shallow-threaded implant(Anyridge, Megagen, Seoul, Korea) (ST). Other than thread shape, the two implant types had identical features, including a nanostructured calcium-coated surface(XPEED, Megagen, Seoul, Korea). The dimensions of the implants were as follows: 3.5 mm in diameter, 7 mm in length, and 2.7 mm in core diameter for the ST; and 5.5 mm in diameter, 7 mm in length, and 3.2 mm in core diameter for the DT. The ST had a 0.8-mm pitch and 0.4-mm depth, whereas the DT had a 0.8-mm pitch and 1.15-mm depth. Implant placement was initially randomized. Thereafter, implants were placed in an alternating manner.

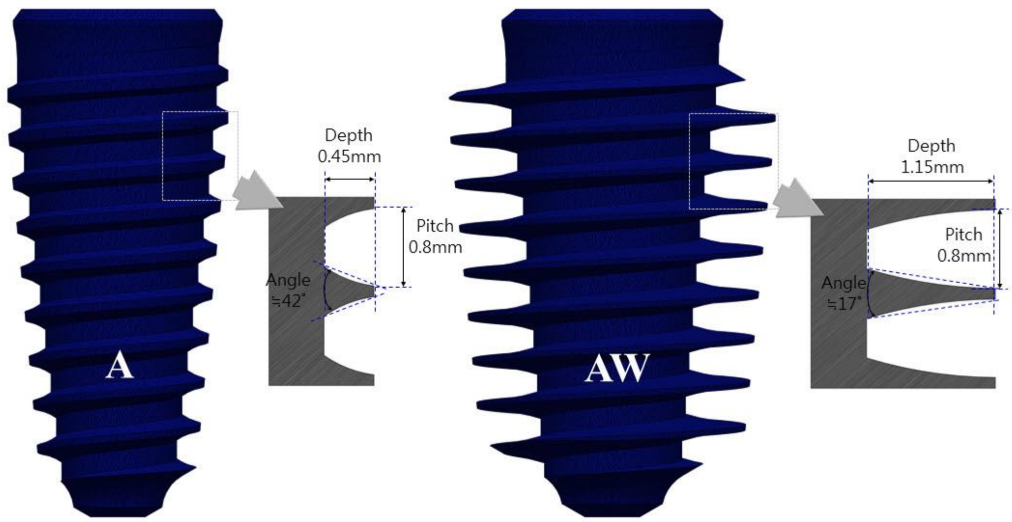

Figure. 1. Schematic figure of the two implant types tested. A, Anyridge®; AW, Anyridge Wide®.

2) Animal model

This study was carried out with approval from the Ethics Committee on Animal Experimentation of Chun Nam University. Five beagle dogs (~1.5 years old, ~13–15 kg in weight) were used for this study. The dogs were given 2 weeks to acclimate to their environment before the experiment. They were fed a soft dog-food diet and had free access to water.

3) Experimental procedures

The dogs underwent extraction of the left mandibular premolars and first molar (P_2, P_3, P_4, and M_1), followed by extraction of the right mandibular premolars and first molar 1 month later. A total of 20 implants were inserted bilaterally in the mandibles of the 5 dogs. Implants were inserted in the left and right mandibular sockets 2 and 3 months later, respectively, allowing a 3-month healing period for each side of the mandible (Figure 2).

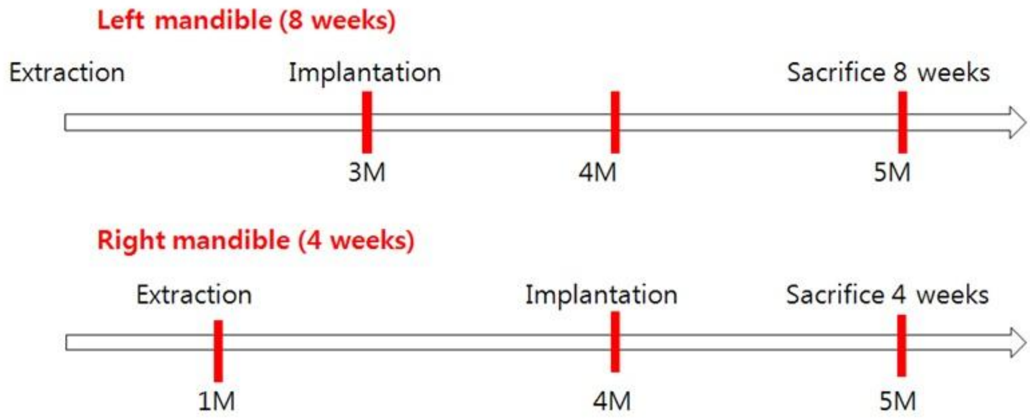

Figure 2. Experiment timeline. M, month.

Before anesthesia, each dog was given intravenous (IV) cimetidine(JW Pharmaceutical, Seoul, Korea) (5 mg/kg) and IV cefazolin(Chong Kun Dang Pharm, Seoul, Korea) (20 mg/kg). Anesthesia was induced by medetomidine(Pfizer Animal Health Korea, Seoul, Korea) (48 μg/kg), a tiletamine/zolazepam mixture(Virbackorea, Seoul, Korea) (3 mg/kg), and tramadol hydrochloride(Huons, Seongnam, Korea) (5.4 mg/kg). Anesthesia was maintained with isoflurane(Choongwae Co., Seoul, Korea) in 100% oxygen. The surgical site was prepared with a 1-ml injection of lidocaine(Yu-Han Co., Gunpo, Korea) containing a 1:100,000 dilution of epinephrine. The teeth were extracted carefully to avoid damaging the extraction sites, which were then closed with 4-0 polyglycolic acid sutures(Surgisorb, Samyang Co., Seoul, Korea). Sutures were removed after 1 week, and the extraction sites were allowed to heal for 3 months.

For implant placement, dogs were sedated and local anesthesia was injected. An incision was made at the bone crest, and a mucoperiosteal flap was reflected on the buccal and lingual sides. Implant sites were prepared with a low-speed drill series and saline irrigation. The final diameters of the drill bits used for the ST and DT implants were 2.9 and 3.3 mm, respectively. Thereafter, implants were inserted at the bone crest level. A healing abutment was connected to each fixture. Finally, the flaps were closed with 4-0 polyglycolic acid sutures. The dogs were kept on a soft diet for 2 weeks after the surgical procedure.

Amoxicillin(Dong Wha Pharm, Seoul, Korea) (20 mg/kg, twice a day) and meloxicam(Boehringer Ingelheim Vetmedica GmbH, Ingelheim, Germany) (0.1 mg/kg, once a day) were administered orally for 7 days postoperatively. Plaque control was maintained by daily flushing of the oral cavity with 0.12% chlorhexidine gluconate for 2 weeks. The animals were anesthetized and killed 8 weeks postsurgery by IV injection of concentrated potassium chloride(Daejung, Sigeung, Korea). Block sections that included the implants, alveolar bone, and surrounding mucosa were collected.

4) Resonance frequency measurements

Resonance frequency measurements were performed at the time of each surgery and at death to assess the mechanical stability of the implants. One examiner performed all resonance frequency testing using an Osstell meter(Osstell Mentor, Integration Diagnostics, Göteborg, Sweden) and a Smart peg(Osstell, Straumann AG, Basel, Switzerland). Implant stability quotient (ISQ) values were measured on the buccal and lingual sides of the implants.

5) Radiography

Intraoral radiographs were taken 3 months after each extraction (at the time of implant placement) and at death to measure marginal bone loss. Radiographs were taken with a portable device(Elytis, Trophy, France) in accordance with the parallel cone technique (70 kV, 8 mA, 0.250 s). A 5.5-mm spherical metal bearing was placed to aid length measurement (Figure 3).

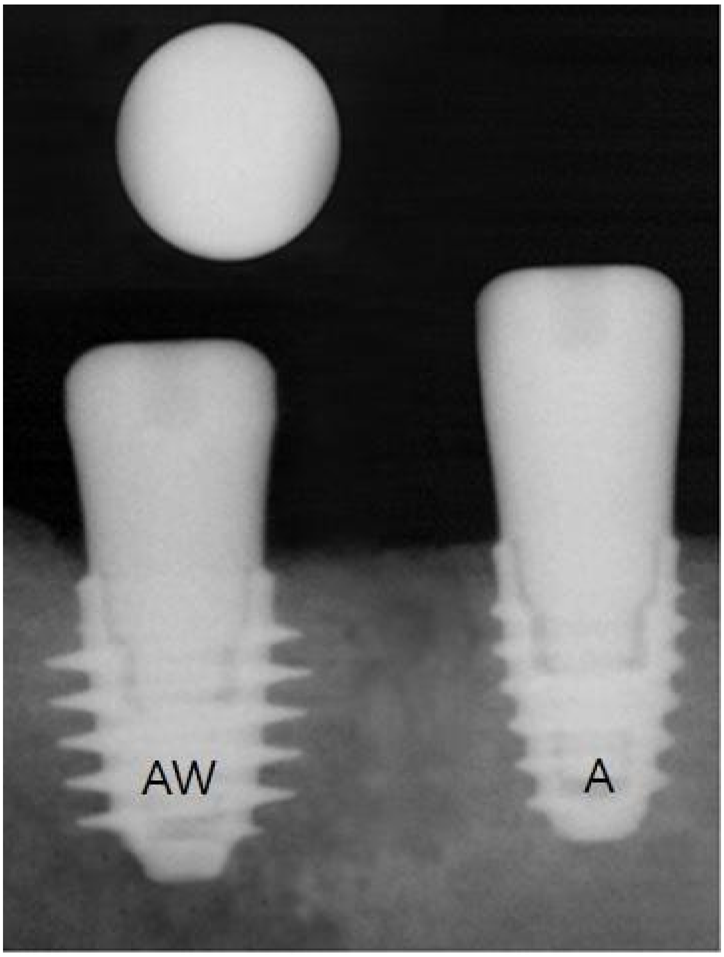

Figure 3. Intraoral radiograph with 5.5-mm spherical metal bearing. A, Anyridge®; AW, Anyridge Wide®.

6) Micro-computed tomography (μCT)

Bone blocks containing one implant each were dehydrated in 70% ethanol and wrapped in parafilm(SERVA Electrophoresis GmbH, Heidelberg, Germany) to prevent drying during tomographic examination. For quantitative 3D analysis, each specimen was placed vertically into the sample holder of a desktop x-ray μCT system(Skyscan 1076 desktop x-ray μCT system, Skyscan, Kontich, Belgium), with the long axis of the implant perpendicular to the scanning beam. High-resolution images were obtained with an 18-μm voxel resolution.

Cone-beam reconstruction was performed with software(Nrecon V1.4, Skyscan, Kontich, Belgium). A constant region of interest (ROI) was defined along the length of the implant gap with the software(CTAn V1.8, Skyscan, Kontich, Belgium). The ROI included 32 pixels of bone surrounding the implant. For all images, a threshold was selected manually to isolate bone tissue and preserve the visualization of its morphology while excluding implant material. BIC and bone-to-implant volume (BIV) ratios were calculated at the crestal portion of each implant. To facilitate examination of the soft-tissue border around implants, barium sulfate(E-Z-HD-barium sulfate powder; E-Z-EM Company Inc., Lake Success, NY) was diluted 1:1 in water and applied to the soft tissue around the implants. Barium sulfate has been used previously to expose soft-tissue deficiencies on radiographs and is an inexpensive, simple, and reliable method for evaluating and visualizing dentoalveolar structures(H. Oktay and N. Kilic, 2014). Soft-tissue height was measured from the implant fixture-abutment junction to the top of the soft tissue on the buccal aspect (Figure 4).

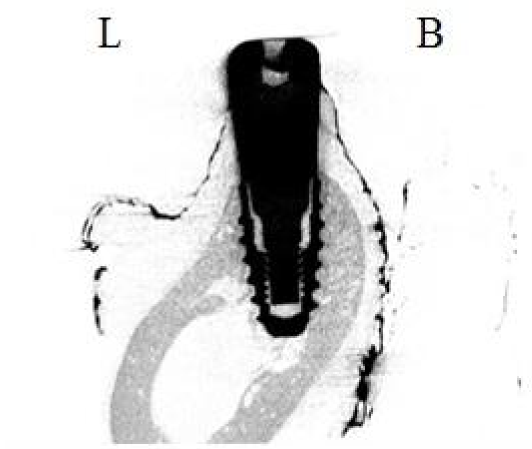

Figure 4. View of soft tissue boundary with barium sulfate in μCT analysis. B, buccal; L, lingual.

7) Histological preparations and histomorphometric evaluation

Tissues containing the implants were removed *en bloc*, fixed in 4% neutral-buffered formaldehyde, dehydrated using an ascending series of alcohols, and embedded in methyl methacrylate for undecalcified sectioning. Undecalcified cut and ground sections containing the central parts of the implants were produced at a final thickness of 20 μm with a macro-cutting and grinding system(Exakt 310 CP series; Exakt Apparatebau, Norderstedt, Germany). The sections were stained with Villanueva, and histomorphometric analysis was carried out under a light microscope(CX31; Olympus, Tokyo, Japan) with an image analysis system(Analysis TS Auto; Olympus) at 50× magnification.

One examiner calculated BIC, defined as the length fraction (%) of mineralized bone in direct contact with the implant surface. Bone density, defined as the surface fraction (%) of the bone surface present in the area of the fixture thread was also calculated. BIC and bone density analyses were confined to the neck portion on the buccal and lingual sides. To evaluate bone loss and soft tissue height, the distances from the abutment-fixture junction to the first bone contact point and to the highest position of soft tissue were measured on the buccal side.

8) Statistical analyses

All statistical analyses were performed with R software, version 3.1.1. The nonparametric repeated-measures analysis of variance method developed by Brunner & Langer (2000) was used to compare values between time points (4 and 8 weeks) and groups, and time × group interactions. The Mann-Whitney U test was also used with Bonferroni *post hoc* correction to detect the sources of significant statistical differences. For each statistical comparison, only the model with the most precise outcome (narrowest 95% confidence interval of the difference) was considered. Differences were considered significant when P values were <0.05.

II. Results

Postoperative healing was uneventful in both groups, with no remarkable complications being observed. Postoperatively, there were no open wounds, infections, or lost implants. All 20 implants exhibited successful integration at the time of death (Figure 5). The median ISQ value for the DT group was 72.87, compared to 70.28 for the ST group. Resonance frequency testing revealed no significant differences between the two implants. Radiographically, bone loss was also statistically similar between the two groups (Table 1).

Figure 5. Intraoral photograph 8 weeks after implant surgery. No remarkable swelling or bleeding was observed. A, Anyridge®; AW, Anyridge Wide®.

Table 1. Group comparison of ISQs, determined by resonance frequency tests, and bone loss measurements, determined by intra-oral radiography.

Parameter	Time post-op.	Group, median value ± SD (min, max)		*P* values		
		DT	ST	Time	Group	Time*group
ISQ	0 days	71.45 ± 5.22 (64.95, 78.25)	70.1 ± 4.07 (66, 75.50)	0.48	0.24	0.22
	4 weeks	73.95 ± 4.36 (67.25, 78)	70.25 ± 5.17 (63.50, 76.75)			
	8 weeks	73.22 ± 3.24 (69.50, 74.75)	70.50 ± 3.43 (66.5, 75.25)			
Bone loss, mm	4 weeks	0.08 ± 0.14 (0, 0.26)	0.11 ± 0.24 (0, 0.34)	0.12	0.58	0.41
	8 weeks	0.16 ± 0.38 (0, 0.33)	0.18 ± 0.32 (0, 0.31)			

ISQ, implant stability quotient; Post-op., postoperative; SD, standard deviation.

Although no main effects of time or group were observed, we did observe significant time*group interactions for BIC values determined by both μCT (Table 2) and histomorphometric analysis (Table 3). Bonferroni *post hoc* analysis revealed that BIC values were lower for the DT group than for the ST group at 4 weeks (μCT, p = 0.01; histomorphometric analysis, p = 0.003), but not 8 weeks. BIV and soft-tissue height did not differ significantly across groups or time points, and did not present any significant interactions.

Table 2. Group comparison of BIC, BIV, and soft tissue height data from µCT.

Parameter	Time post-op.	Group, median value ± SD (min, max)		*P* value		
		DT	ST	Time	Group	Time*group
BIC %	4 weeks	49.51 ± 4.64 (46.57, 54.87)	53.62 ± 5.51 (47.40, 57.91)	0.32	0.22	*0.04
	8 weeks	55.08 ± 2.72 (52.49, 59.25)	53.88 ± 3.10 (52.59, 61.62)			
BIV %	4 weeks	41.32 ± 6.05 (36.46, 49.17)	42.23 ± 5.49 (38.91, 49.33)	0.34	0.57	0.42
	8 weeks	44.78 ± 7.13 (37.21, 53.60)	45.49 ± 5.18 (39.24, 47.97)			
Soft-tissue height, mm	4 weeks	1.34 ± 0.73 (0.85, 2.06)	1.45 ± 0.32 (1.14, 2.04)	0.37	0.42	0.19
	8 weeks	1.28 ± 0.49 (0.78, 1.83)	1.39 ± 0.87 (0.89, 2.29)			

BIC, bone to implant contact; BIV, bone to implant volume; Post-op., postoperative; SD, standard deviation.
*$p < 0.05$; Bonferroni post hoc group comparison at 4 weeks, $p = 0.01$.

Table 3. Group comparison of BIC, bone density, soft tissue height, and bone loss data from histomorphometric analysis.

Parameter	Time post-op.	Group, median value ± SD (min, max)		*P* values		
		DT	ST	Time	Group	Time*group
BIC %	4 weeks	48.39 ± 8.62 (44.74, 55.82)	56.87 ± 5.31 (49.62, 56.90)	0.41	0.08	*0.01
	8 weeks	57.23 ± 10.88 (50.71, 68.06)	53.08 ± 8.19 (51.27, 66.83)			
Bone density %	4 weeks	42.72 ± 5.46 (35.11, 49.40)	44.69 ± 5.21 (40.54, 54.60)	0.56	0.33	0.25
	8 weeks	46.19 ± 4.97 (39.95, 49.05)	45.40 ± 8.37 (38.17, 50.21)			
Bone loss, mm	4 weeks	0.28 ± 0.21 (0, 0.59)	0.21 ± 0.15 (0, 0.42)	0.61	0.37	0.82
	8 weeks	0.17 ± 0.24 (0, 0.48)	0.23 ± 0.29 (0, 0.65)			
Soft-tissue height, mm	4 weeks	2.51 ± 1.89 (1.74, 2.92)	2.99 ± 1.28 (2.38, 3.02)	0.39	0.24	0.27
	8 weeks	2.71 ± 2.73 (1.42, 3.29)	2.43 ± 1.70 (1.99, 3.38)			

BIC, bone to implant contact; BIV, bone to implant volume; Post-op., postoperative; SD, standard deviation.
*$p < 0.05$; Bonferroni post hoc group comparison at 4 weeks, $p = 0.003$.

III. Discussion

The present study demonstrated that although deep thread depth is intended to create more surface area for implant-tissue interaction, and thus to thereby potentially enhance osseointegration, our DT group had, temporarily, a lower BIC than our ST group. The difference was evident at 4 weeks in both our μCT and histomorphometic experiments at 4 weeks. By 8 weeks, BIC values did not differ significantly between the two groups. Meanwhile, ISQ values, bone loss, bone density, and soft tissue height were similar between the two groups 4 weeks and 8 weeks postoperatively.

The lower BIC value of the DT group at 4 weeks observed in this study is likely due to the healing chambers that form between a newly inserted implant and surrounding bone(T. Berglundh et al., 2003). During implant insertion, the tendency to cut into surrounding bone increases with the depth of the threads. For this reason, DT implants may be left with relatively less direct bone contact than ST implants, resulting in larger healing chambers and, consequently, lower BIC values. The catching up of the DT group's BIC ratios with those of the ST group by 8 weeks can be explained by implant surface modification (Figure 6). In a previous *in vivo* study(T. Berglundh et al., 2003) using custom implants with wound chamber models, peri-implant bone healing was related to contact and distant osteogenesis. Implant surface modification is known to accelerate this healing process. For example, greater osseointegration has been observed with sand-blasted and acid-etched implants, characterized by osteophilic surfaces, than with turned implants(I. Abrahamsson et al., 2004). Likewise, strong bone integration has also been described for titanium implants with nanostructured calcium-coated surfaces(SY Lee et al., 2012; SY Lee et al., 2012).

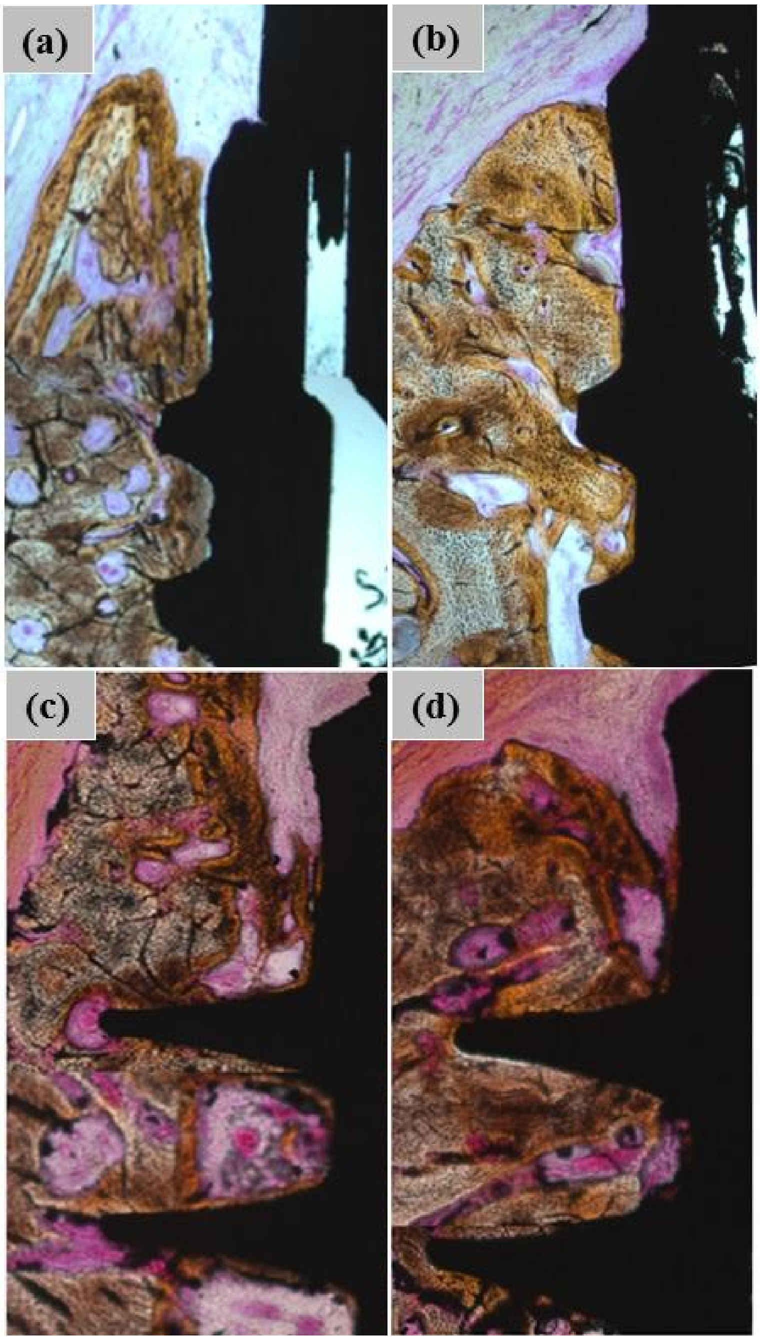

Figure 6. Implants viewed at 50× magnification 4 weeks (left) and 8 weeks (right) after implantation. (a, b) Anyridge®, (c, d) Anyridge Wide®.

The temporary nature of the lower BIC values for the DT group in this study differs from the observations in a previous study reporting lower BIC values with deeper threading persisting to at least 5 weeks(C. Marin et al., 2010). The former study was conducted on beagle mandibles with various implant configurations to allow the formation of various healing chamber dimensions after implantation. The triangular configuration implant group with deep threads (1-mm thread depth, 0.6-mm pitch) showed significantly lower BIC values at both 3 and 5 weeks than the other implant configuration groups with shallower thread depths. The lower BIC value at 5 weeks result was likely due to the inability of blood to fully wet the extent of the chamber around the triangular configuration implants and form clots to act as scaffolds(Davies, 2003). The absence of blood clot hinders bone formation at the deeper portion of the healing chamber(C. Marin et al., 2010).

Good primary stability of implants is not difficult to achieve in dense bone. Conversely, in low-density bone, various implant design modifications are utilized to achieve adequate primary stability(E. Misch and Density, 1999). It has been supposed that implant design modifications aimed at increasing BIC (e.g., through changes in thread number and shape) could improve primary stability and thus improve final outcomes for patients(Chun et al., 2002). Among the design variables examined, thread pitch has had the greatest effect on implant surface area(Misch, 2007). Thread pitch and depth might be particularly important in low-density regions where implant parameters such as length are limited by the local bone anatomy(E. Orsini et al., 2012). For example, when an ideal implant length cannot be used without prior bone augmentation, it is hoped that an implant with a greater thread number and deeper threading might improve the functional surface area for poorly structured and atrophic alveolar ridges.

To our knowledge, this is the first report to provide controlled experimental data concerning the influence of thread depth on peri-implant tissues in the neck area in terms of BIC and hard- and soft-tissue dimensions. It should be noted that the compared fixtures in this study had the same surface treatment(XPEED, Megagen, Seoul, Korea), thread shape, thread pitch, and thread helix angle. The only differing characteristic was thread depth.

Owing to its ease of use and noninvasive character, resonance frequency analysis has been used in the clinical setting to measure the mechanical stability of implants in relation to osseointegration(S. Lachmann et al., 2006; S. Lachmann et al. 2006; JS Oh et al., 2009). Resonance frequency analysis produces ISQ values in the range of 1–100, wherein values less than 45 indicate implant failure and values above 60~70 indicate success(L. Sennerby and J. Roos, 1997). Meanwhile, μCT has been validated for the 3D assessment and analysis of BIC and BIV in trabecular bone(R. Müller, 2002).

BIC is an important measure of implant stability and osseointegration(Klokkeyold et al., 1997), whereas BIV provides information about the thickness of newly formed peri-implant bone tissue(R. Bernhardt et al., 2012). The level of supporting bone and the dimensions of the surrounding soft tissue depend on surgical and prosthetic parameters, as well as other related variables(Belser et al., 2004). Most studies of tooth structure have used two-dimensional histological images. However, serial histological sectioning is time consuming and destructive, and two-dimensional methods can result in errors of orientation in the section plane due to the anisotropic features of structures.

In the present study, all implants survived throughout the study period. Oral hygiene was stable in all five dogs, and no gingival problems (e.g., swelling or pus discharge) were observed. Both implant types yielded ISQ values greater than 70, indicating successful and stable fixation. The high BIC values obtained from our μCT analysis indicate good implant stability, which, clinically, enables functional dental reconstruction.

The success and predictability of tooth replacement with endo-osseous implants are dependent on primary stability and subsequent osseointegration(D. Schwartz-Arad et al., 2005). A number of factors may influence primary stability(Misch, 1990), including implant design(Triplett et al., 2003). In particular, thread depth substantially affects the total implant surface area, with a greater thread depth providing a greater surface area(Misch, 2007). In a previous 3D FEA study(L. Kong *et al*, 2008) using V-shaped threads, Kong *et al.* examined how variations in thread depth (0.2–0.6 mm) and width (0.1–0.4 mm) affected implant responses to forces (100 N and 50 N) applied parallel to and at a 45° angle to the long axis of the implant. They determined that the optimal thread depth was in the range of 0.34–0.5 mm, with an optimal thread width in the range of 0.18–0.3 mm. They found that thread depth was more sensitive than thread width to peak stresses. Notwithstanding, the present work is the first to examine the influence of thread depth on the osseointegration of implants *in vivo* without functional loading.

In this study, μCT analysis was performed within a defined ROI, namely, the implant neck area and surrounding region 10–32 pixels away from the fixture surface. This ROI was selected to eliminate the confounding effects of metal artifacts. Therefore, our BIC and BIV values derived from μCT do not correspond precisely with our histological data. Previous studies(H. Sarve et al., 2011; M. Freilich et al., 2009; N. Stoppie et al., 2005; C. Schouten et al., 2009) have reported contradictory results regarding whether a correlation exists between μCT and histological analysis. Factors such as metal artifacts, threshold level, voxel size, image resolution, and cutting direction of the scan may affect the results of μCT analysis(S. Vandeweghe et al., 2013). Meanwhile, the results of histological analysis may be influenced by cutting direction and slice thickness. Hence, since both analyses can be affected by numerous factors, inconsistent results can be derived from the same objects.

Our negative results regarding thread depth effects specifically in this study are consistent with prior studies that compared implants with differing pitch and thread depth. For example, a previous clinical study(YI Kang et al., 2012) reported that thread size at the implant neck area did not affect the amount of radiographic marginal bone loss during the initial first year physiologic bone remodeling period. Furthermore, a recent animal study(JY Choi et al., 2015) revealed no differences in radiographic data, μCT data, or histologically deterimined peri-implant hard- and soft-tissue dimensions between implant types with different thread sizes in the implant neck area. Thus, these findings suggest that implant design modifications involving thread depth (this study) and pitch and in the implant neck area do not influence peri-implant hard- and soft-tissue dimensions.

This study had several limitations. Firstly, the implants were inserted in extremely dense bone only. Other limitations include the small sample size and the short study period, which did not allow for long-term observation, such as following function assessments with prosthetic teeth and occlusal loading. Despite these limitations, the present findings suggest that implants with shallow- versus deep-threaded necks, under otherwise identical conditions, produce similar results in peri-implant tissues after 8 weeks of healing.

IV. Conclusions

In the early healing phase, significantly lower BIC values were observed for implants with deep-threaded neack than for implants with shallow-threaded necks. However, as healing progressed, no significant differences in peri-implant hard or soft tissues were observed in the implant neck region when dogs received dental implants of different thread depths.

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V. References

1. Geng JP, Ma QS, Xu W, Tan KB, Liu GR. Finite element analysis of four thread-form configurations in a stepped screw implant. *J Oral Rehabil* 2004;31:233-239.
2. Geng JP, Xu DW, Tan KB, Liu GR. Finite element analysis of an osseointegrated stepped screw dental implant. *J Oral Implantol* 2004;30:223-233.
3. Misch CE. *Contemporary implant dentistry.* Jefferson City. Elsevier Health Sciences; 2007.
4. Marin C, Granato R, Suzuki M, et al. Histomorphologic and histomorphometric evaluation of various endoosseous implant healing chamber configuration at early implantation times: a study in dogs. *Clin Oral implants Res* 2010;21:577-583.
5. Kong L, Hu K, Li D, et al. Evaluation of the cylinder implant thread height and width: a 3-dimensional finite element analysis. *Int J Oral Maxillofac Implants* 2008;23:65-74.
6. Oktay H, Kiliç N. Evaluation of the inclination in posterior dentoalveolar structures after rapid maxillary expansion: a new method. *Dentomaxillofac Radiol.* 2014;36:356-359.
7. Berglundh T, Abrahamsson I, Lang NP, Lindhe J. De novo alveolar bone formation adjacent to endosseous implants. A model study in the dog. *Clin Oral Implants Res* 2003;14:251-262.
8. Abrahamsson I, Berglundh T, Linder E et al. Early bone formation adjacent to rough

and turned endosseous implant surfaces. An experimental study in the dog. *Clin Oral Implants Res* 2004;15:381-392.

9. Lee SY, Yang DJ, Yeo S, et al. Effect of XPEED® on Ti implants with deep threads. *Key Eng Mater* 2012;493:442-446.
10. Lee SY, Yang DJ, Yeo S, An HW, Ryoo KH, Park KB. The cytocompatibility and osseointegration of the Ti implants with XPEED® surfaces. *Clin Oral Implants Res* 2012;23:1283-1289.
11. Davies JE. Understanding peri-implant endoosseous healing. *J Dent Educ* 2003;67:932-949.
12. Misch E, Density CB. A key determinant for clinical success. *Comtemporary Implant Dentistry.* St Louis: Mosby Co; 1999:109.
13. Chun HJ, Cheong SY, Han JH, et al. Evaluation of design parameters of osseointegrated dental implants using finite element analysis. *J Oral Rehabil* 2002;29:565-574.
14. Orsini E, Giavaresi G, Trire A, Ottani V, Salgarello S. Dental implant thread pitch and its influence on the osseointegration process: an in vivo comparison study. *Int J Oral Maxillofac Implants* 2012;27:383-392.
15. Lachmann S, Jäger B, Axmann D, Gomez-Roman G, Groten M, Weber H. Resonance frequency analysis and damping capacity assessment. Part I: an in vitro study on measurement reliability and a method of comparison in the determination of primary dental implant stability. *Clin Oral Implants Res* 2006;17:75-79.

16. Lachmann S, Laval JY, Jager B, et al. Resonance frequency analysis and damping capacity assessment. Part 2: peri-implant bone loss follow-up. An in vitro study with the Periotest and Osstell instruments. *Clin Oral Implants Res* 2006;17:80-84.
17. Oh J-S, Kim S-G, Lim S-C, Ong JL. A comparative study of two noninvasive techniques to evaluate implant stability: Periotest and Osstell Mentor. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;107:513-518.
18. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. *Int J Prosthodont* 1997;11:408-420.
19. Müller R. The Zürich experience: one decade of three-dimensional high-resolution computed tomography. *Top Magn Reson Imaging* 2002;13:307-322.
20. Klokkevold PR, Nishimura RD, Adachi M, Caputo A. Osseointegration enhanced by chemical etching of the titanium surface. A torque removal study in the rabbit. *Clin Oral Implants Res* 1997;8:442-447.
21. Bernhardt R, Kuhlisch E, Schulz MC, Eckelt U, Stadlinger B. Comparison of bone-implant contact and bone-implant volume between 2D-histological sections and 3D-SRµCT slices. *Eur Cells Mater* 2012;23:237-248.
22. Belser UC, Schmid B, Higginbottom F, Buser D. Outcome analysis of implant restorations located in the anterior maxilla: a review of the recent literature. *Int J Oral Maxillofac Implants* 2004;19:30-42.
23. Schwartz-Arad D, Herzberg R, Levin L. Evaluation of long-term implant success. *J Periodontol* 2005;76:1623-1628.

24. Misch CE. Density of bone: effect on treatment plans, surgical approach, healing, and progressive boen loading. *Int J Oral Implantol* 1990;6:23-31.
25. Triplett RG, Frohberg U, Sykaras N, Woody RD. Implant materials, design, and surface topographies: their influence on osseointegration of dental implants. *J Long Term Eff Med Implants* 2003;13:485-501.
26. Sarve H, Lindblad J, Borgefors G et al. Extracting 3D information on bone remodeling in the proximity of titannium implants in SRmμCT image volumes. *Comput Methods Programs Biomed* 2011;102:25-34
27. Freilich M, Shafer D, Wei M, Kompalli R, et al. Implant system for guiding a new layer of bone. Computed microtomography and histomorphometric analysis in the rabbit mandible. *Clin Oral Implants Res* 2009;20:201-207.
28. Stoppie N, van der Waerden JP, Jansen JA, et al. Validation of microfocus computed tomography in the evaluation of bone implant specimens. *Clin Implant Dent Relat Res* 2005;7:87-94.
29. Schouten C, Meijer GJ, van den Beucken JJ, et al. The quantitative assessment of peri-implant bone responses using histomorphometry and micro-computed tomography. *Biomaterials* 2009;30:4539-4549.
30. Vandeweghe S, Coelho P, Vanhove C et al. Utilizing micro-CT to evaluate bone structure surrounding dental implants: a comparison with histomorphometry. *J Biomed Mater Res B Appl Biomater* 2013;101:1259-1266
31. Kang YI, Lee DW, Park KH et al. Effect of thread size on the implant neck area:

preliminary results at 1 year of function. *Clin Oral Implants Res* 2012;23:1147–1151.

32. Choi JY, Moon IS, Yun JH et al. Effect of thread size in the implant neck area on peri-implant hard and soft tissues: an animal study. Clin Oral Implants Res 2015;00:1-6. Epub ahead of print.

국문요약

임플란트 경부에서 임플란트 나사선의 깊이가 임플란트 주변 경조직 및 연조직에 미치는 영향: 동물실험

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이 동물실험의 목적은 임플란트 경부에서 나사산의 깊이가 임플란트 주변 조직에 미치는 영향을 BIC와 경조직, 연조직의 관점에서 알아보기 위함이다.

5마리의 비글견의 소구치들과 제1대구치의 발치 3개월 후에 임플란트가 식립되었다. 치유된 발치와에 두 가지 임플란트 (Anyridge®와 Anyridge Wide ®)가 식립되었다. 임플란트 식립 후, 식립 후 4 주째, 8 주째 시점에서 공진주파수시험을, 임플란트 식립 후 4 주째, 8 주째 시점에서 구강 내 방사선학적 분석, 미세 컴퓨터 단층촬영, 조직계측학적 분석이 시행되었다. 공진주파수시험에서 두 군 간의 통계학적 유의성은 없었다. 구강 내 방사선학적 분석에서 Anyridge®군에서 Anyone Wide®군 보다 더 많은 골흡수를 보였지만 통계학적 유의성은 없었다. 미세 컴퓨터 단층촬영 분석에서 Anyone Wide®군이 Anyone®군보다 4주 째 BIC의 비율이 유의성 있게 낮았지만 (P=0.01), 8주 째 BIC 비율은 유의성 있는 차이를 나타내지 않았다. BIV 값, 그리고 연조직 높이에서 두 군 내에 유의성 있는 차이는 없었다. 조직학적 분석에서 Anyone Wide®군이 Anyone®군보다 4주 째 BIC의 비율이 유의성 있게 낮았지만

(P=0.003), 8주 째 BIC 비율은 유의성 있는 차이를 나타내지 않았다. 골밀도나 골소실에서 두 군 내에 유의성 있는 차이는 없었다.

8 주째 시점에서, 깊은 나사산을 가지는 임플란트는 얕은 나사산을 가지는 임플란트와 임플란트 주변 경조직 및 연조직 측면에서 차이를 보이지 않는 것으로 나타났다.

핵심 단어: 동물 실험, 컴퓨터 단층촬영, 조직학적 분석