The influence of different neck design on
Marginal bone tissue in dogs

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Abstract

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Statement of purpose. Loss of the marginal bone to the first thread have been accepted but continuous effort have been made to reduce this bone loss by varying implant design and surface texture. Few of currently available implants in the market have claimed to have improved to overcome this problem.
Purpose. This animal study has examined the histomorphometric variations between implants with micro-thread, micro-grooved and turned surfaced neck designs.
Materials and methods. Mandibular premolars from four mongrel dogs have been removed and left to heal for three months. One of three different implant systems with turned neck, micro-thread and micro-grooved for their implant neck design were placed according to the manufacturers' protocol and left submerged for 8 and 12 weeks. These were then harvested for histological examination.
All specimens have shown uneventful healing for the duration of the experiment.
Results. The histological slides have shown that all samples had ossointegrated successfully and there were active bone remodelling adjacent to implants were observed. With the micro-grooved implants 0.40mm and 0.26mm of the marginal bone level changes were observed at 8 and 12 weeks respectively. The micro-threaded implants had changes of 0.79mm and 0.56mm. The turned neck designed implants had marginal bone level changes of 1.61mm and 1.63mm in 8 and 12 weeks specimens.

A complex soft tissue arrangement has been observed against micro-threaded and micro-grooved implants.

Conclusion. Within the limitations of this study, it could be concluded that implants with micro-grooved had the least and the turned neck designed implants had the most changes in the marginal bone level. The macro textured implant surfaces affect soft tissue responses.

Key words: micro texture, marginal bone level, implant design

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1. Introduction

The initial implant design used by Brånemark at the start of developing endosseous dental implants is commercially no longer available. This is not question on the lack of success rate. At the early report of osseointegrated dental implant, 15 year follow up study have reported success rates of 81% in maxilla and 91% in mandible, with marginal bone loss of 1.5mm in the first year and approximately 0.1mm annually from there after.[1] This already satisfied the success criteria which have been published in the years to come which are clinical stability, in function without any symptoms and with minimal bone resorption of less than 0.2mm annually after the first year of the implantation.[2, 3] The success of osseointegration of dental implant has been successfully determined by many clinical studies in different implant designs and clinical situations which the implants have been exposed.[4, 5, 6]

With increase in the success of endosseous implants and variations in the clinical situations and applications of these however, have led to new expectations from dental implants from both patients and clinicians. The increase in the longevity of implant, have led to a view that, it may not be acceptable to have implants continuously to loose marginal bone of approximately 0.2mm annually. The United States National Institutes of health consensus conference in 1988 have made a point in the concerns of stable marginal bone level and advised clinical studies to have longitudinal evaluation of bone level measurements for an accurate implant evaluation.[7] When placing implant supported fixed prosthesis, especially in the anterior region, the success not only depends on the functional aspect of the dentistry performed but the aesthetic has important proportion in patient satisfaction to the treatment. [8]

The expected demands have led the clinician to increase their understanding and their skills in implantation and restoration of the prosthesis.[9, 10] In conjunction with these many attempts have been made in improving the design, texture and surface chemistry of the implants. Many of these are commercially available although some may only have a short commercial life. [11, 12]

Of many variations to the directions in the development, implant neck design is one of them. Smooth conical design by Brånemark, threaded conical design, straight polished neck, rough surfaces to the bone level are few of the examples of varying designs.[7, 13, 14]

Micro-textured surface and the macro-textured surface have been explored. These designs mainly aimed to retain the marginal bones which are expected to be lost in the first year of implantation.[15]

The texture which has been suggested for a smooth surface at the early stage of implant development faces different approaches. An animal study by Abrahamsson et al has shown the marginal bone level differences between three different implant designs have shown no statistical significance.[16] In Astrand, rough neck surfaced neck implant and turned surface was compared for 5 years. The measurements were better in the rough surfaced neck implant but there was no statistical significance.[17]

The macro texture for retentive design has considered the peak interfacial shear stress on the marginal bone area on the loading. By designing the retentive form, it has been described to have reduced the peak interfacial shear stress at the margin and more stresses were present at the lower part of the implant.[18] On the micro texture implant, retention of hard tissues with the micro-textured surfaces was observed.[19] A favourable soft tissue reactions been claimed in some micro-textured implants.[20]

The aim of the present study was to investigate the influence of three different implant neck designs on marginal bone tissue in dogs at two different time difference.

2. Materials and methods

2.1. Implants used

Four of three different implant designs have been used in this study; turned neck implant (TN), micro-threaded neck implant (MT) and micro-grooved neck implant. (MG) (Figure 1) The turned surfaced implants used in this study had 1mm of turned to produce the surface often referred as a machined surface (Avana implant system, Osstem co. Ltd. Seoul. Korea). The MT implant has pitch of 400μm in 2mm coronal portion the implant and the surface was treated by blasting and acid etching. (Oneplant, Warantec, Seoul, Korea) The upper 2mm of the MG implant has a ‘dual bio-affinity collar’ claimed by the manufacturer with two different types of MG for both soft and hard tissue retention. (Laser-lok, Bio-lok international Inc. Deerfield Beach. USA) Twelve micrometer and 8μm grooves are to be lined next to bone and soft tissue, respectively. The upper portion of the implant is 0.5mm of turned surface, then followed by 0.7mm of MG at pitch of 8μm and 0.8mm of micro-grooves at pitch of 12μm. The surface was treated with resorbable blast and acid etching.

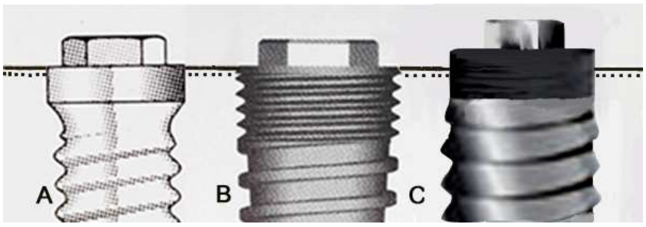


Figure1. Three different types of implant neck designs

A	TN; Turned neck implants
B	MT; Micro-threaded implants
C	MG; Micro-grooved implants
Solid line marginal	bone level at placement of implant
Dotted line	marginal bone level

2.2. Animal experiment

Four mongrel dogs of approximately 1year old and weighed about 30 kg each were used. During the surgical procedures the animals were anesthetised with intravenous administered ketamin 10mg/kg and maintained anaesthesia with profolol 6mg/kg. The operative sites were further anesthetized with lidocaine 2%, adrenaline 1/8000.

In both quadrants premolars 1, 2, 3 and 4 were extracted and the wounds were primarily closed. After healing period of three months, three different implants TN implants with 3.3 mm diameter and 10mm in length, MT implant with 4.0mm diameter and 11mm in length and MG implant with 4mm diameter and 11.5mm in length were placed, according to the manufacturer's recommendation. Each dog received one of each implant types and implants were positioned randomly. Each implant were covered with cover screws and submerged.

Two of the dogs were sacrificed after 8weeks and the third and fourth in 12 weeks after the implantation with overdose of ketamin intravenously. The mandible specimens were immediately placed in 10% formaldehyde solution for fixation. After embedding the specimens in resin block, two sections were prepared in mesio-distal direction at thickness of approximately 60μm and stained for hematoxylin and eosion (H & E) and Masson's trichrome for the alveolar bone pattern and measurements and collagen arrangements in the soft and hard tissue.

2.3. Histomorphometric examination

The examinations were made in an Olympus BH-2 microscope under normal and polarized lights for histological examination. (Olympus Japan)

The images were scanned and histomorphometric measurements were made using imaging analysis system (Image-Pro Plus, Planetron). The program was calibrated before each measurement. The morphometric measurements were measured as written in Sennerby et al [21]and Mohammadi et al.[22] This study was interested in the tissue healing and reaction around the various implant neck designs and the measurements were only carried out on the coronal 2mm of implants.

3. Results

The healing were uneventful however, one of the dogs from the week8 had exposure of the cover screws on one side of the jaw. There was no sign of inflammation or other complications.

3.1. Histomorphometric measurements

Table1. Histomorphometric measurements of three different implants

Implant type	TN		MT		MG	
Weeks	8	12	8	12	8	12
BIC / %	22.28	30.49	21.78	22.56	35.51	41.02
Marginal bone loss / mm	1.61	1.63	0.79	0.56	0.40	0.26
Bone area in threads / %	-	-	64.74	56.55	55.43	44.77

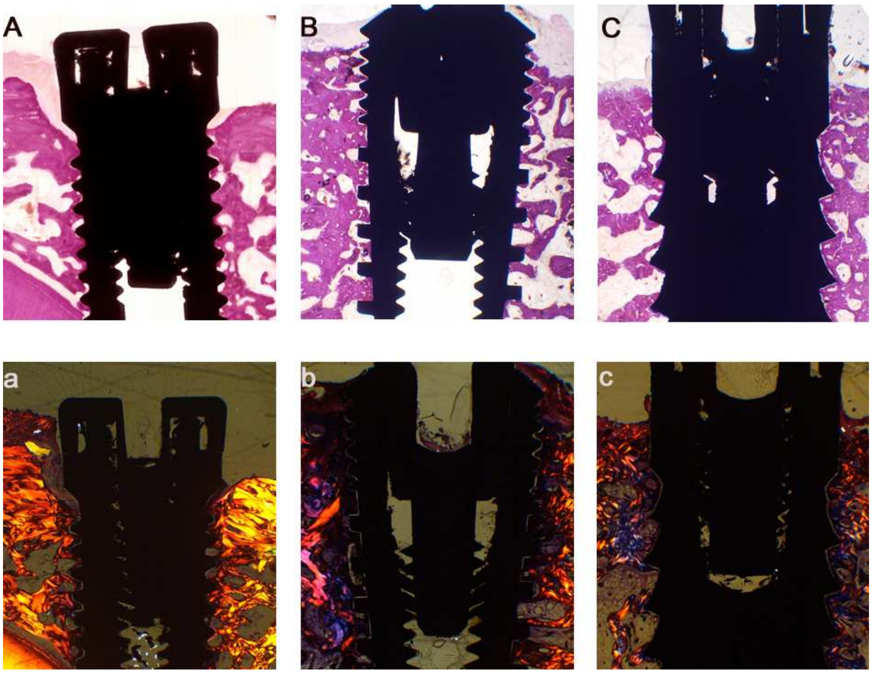
TN : turned neck implants
MT : micro-threaded neck implants
MG : micro-grooved neck implants

The bone-implant–contact areas of coronal 2mm of implants were analysed in this study have shown that the values greater in week12 specimens than in week 8 specimen measurements. The difference between two were minimal in MT implants 21.78% and 22.56% however there were greater in the TN and the MG implants, from 22.28% to 30.49% and 35.51% to 41.02% respectively. Further more the BIC were higher in the MG than any other implant systems. (Table 1)

The marginal bone level measurements were lowest in the TN implants with 1.61mm and 1.63mm, in comparison to MT of 0.79mm and 0.56mm, and MG of 0.40mm and 0.26mm. The bone level was nearest to the original bone level on the fixture with the MG implants than others. Both

MG and MT had increase in the marginal bone level in specimens of week 12 than in week 8. The changes in the measurements of control were negligible.
The bone areas only on the neck portion of retention features were compared between MT and MG implants. As the TN implant had smooth collar at the coronal portion, no bone area in the threads could be measured unless it was taken below the coronal 1mm of the implants. Despite the differences in the marginal bone loss, the percentages of bone filled areas were similar. Unlike the other morphometric measurements MG implants had the lower values of 55.43% and 44.77%, and the values were lower in week 12 than in week 8 in both MT and MG implants.

3.2. Histological examination
There were more bones in the trabecular in the week 12 specimens in comparison to the week 8 specimens. The thickness of cortical bone could generally seem in the former specimens than the latter. Primary and secondary osteons could be seen around the implant. Especially round MT implants there were more remodelling activities could be noted. Under the polarised lights, the mineralised state and the stages of bone remodelling could be more clearly observed. On the bone remodelling, the TN implants were more likely to have lamella bone near the surface of the implants and in both 8 and 12weeks little difference could be noted. In both MT and MG implants a thin layer of less organised bone could be seen especially towards the coronal portion of the implants. MG and MT implants had areas at the marginal bone which were non-polarizing. These areas were greater in the MT group than the MG group and the sizes were smaller in the week 12 specimens than in week 8 specimens. The observed lamella bones were positioned further away from the surface of the implants. (Figure 2)



Turned neck implants   Micro-threaded implants   Micro-grooved implants

Figure 2. Implant specimens in H & E staining and under polarized light. Magnification x10

A, B, C H & E staining

a, b, c Masson's trichrome staining under polarized light

Lamella bone against the control implant on under polarised light could be seen on a TN specimen but the MT and MG slides show less well organized bone. In the margin of bone around MT implants were dark under polarized light, indicating unorganized collagen fibers and mineralization is insufficient.

For the observation of soft tissue Masson's trichrome staining was used where much clear collagen organisation could be seen under the polarized light. The control group with turned surface had its collagens lined up against the implant surface creating typical parallel collagen fibres as expected. (Figure 3)

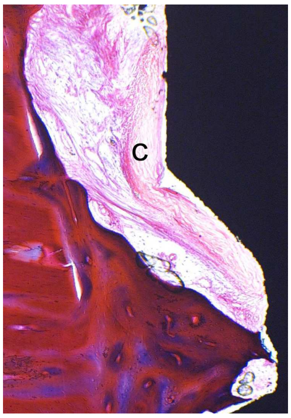


Figure 3. Soft tissue collagen fiber (C) organization in a TN surface implant. Magnification x 100

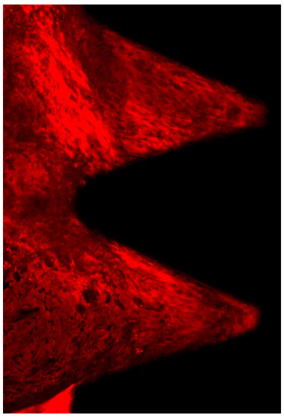


Figure4. Organization of collagen fibre in MT implant neck surface under polarized light. Almost perpendicular like projection of collagen fibres from the thread area can be observed. Magnification X200

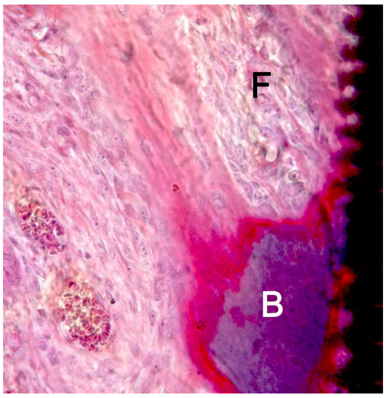


Figure5. Bone attachment (B) over 12μm micro-grooved area and fibroblasts (F) attachments over 8μm micro-grooved area. Magnification x400

In the MT implants the level of the bone was at the level that was expected but some had bone level below this. In the threaded areas that were not attached by the bone, an interesting observation was made. The collagen fibres were parallel to the implants surface as per se but the resulting effect from the thread with 60 degrees angulations had its collagen fibres to organise in the perpendicular to the long axis of the implant. (Figure 4)

The MG implants had bone attachments to the MG surface. Some even had bone attachments to the smaller 8MG areas. (Figure 5) Osteoblasts have been observed in some of MG itself. Over the 8MG surfaces rather than creating collagen fibres in parallel to the long axis of the implants, the collagen organisation was ‘disturbed’ and this layer was least twice of the depth of the grooves. (Figure 6) The fibroblasts had more rounded nuclear than the fibroblasts observed in the control implant surfaces. Clear perpendicular fibres could be seen immediate to the MG surface then followed by some parallel fibres and some circumferential fibres could be seen further away. In the junction between the micro-grooved surface and the turned surface a clear distinction between two different types of the collagen organisation could be seen. A clear distinction between the soft tissue collagen organisation at the grooved surface and the turned surface was noted. (Figure 7)

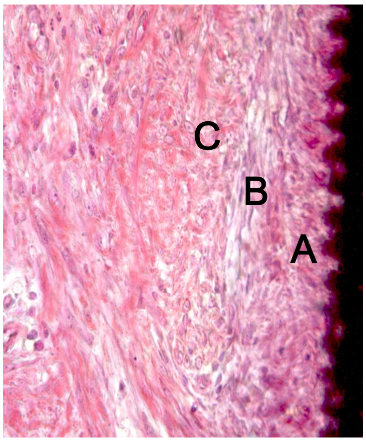
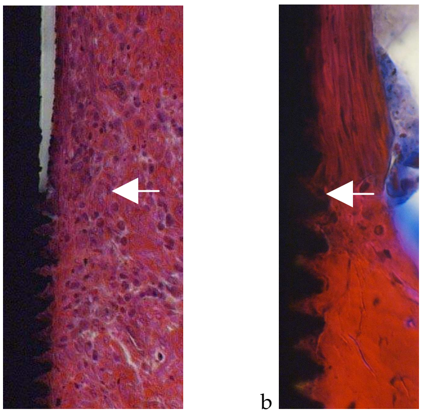


Figure 6. 'Disturbed' layer of soft tissue over the 8µm micro-grooved implant surface.
A Collagen fibers perpendicular in direction from implant surface
B Collagen fibers parallel in the long axis to the implant surface
C Collagen fibers parallel to the circular plane of the implant surface
Magnification x400

TS

8MG



a b

Figure7. The difference in the collagen organization over the two different implant surfaces

The triangle points where the surface changes from 8µm MG (8MG) to turned surface (TS) Note the changes in the sift tissue collagen organization direction. Over the smooth implant area a fibroblasts nucleus and the collagen directions were parallel to the implant surface but over the micro-grooved areas this pattern disappears and some nucleus are circular and no clear organization could be seen in these slides. Magnification x100 (a), x400 (b).

4. Discussion

Achieving a successful osseointegration with an endosseous implant is an accepted result in implant dentistry with high long-term success rate. The on going research and clinical studies have been made on having a natural tooth aesthetics, where successes in osseointegration, maintaining the bone level and stable soft tissue are all part of equation.[9, 23] Tarnow and his colleagues have shown the importance in maintaining the marginal bone height, as the response of the soft tissue height adjacent to the implant depended on the position of the bone level and the surrounding environment.[24] Tarnow et al has shown the clinical conditions and limitations, where a maximum retention of marginal bone and the soft tissue have been described.[10, 24] Not all clinical situations allow to follow all the criteria to meet the satisfying aesthetic result from implant dentistry. There are many clinical methods, such as soft and hard tissue grafting, distraction osteogenesis, combining with orthodontic treatment and, many more to create an ideal edentulous space for an implants but implant fixture design have also been made for more favourable clinical hard and soft tissue response.[25, 26, 27, 28, 29]

In this study a comparisons were made between three implant designs on the hard and soft tissue response. In macro-structural observation made of the specimens has shown not much difference between the bone developmental stages of 8 and 12 weeks of healing. This may have been due to the healing time. This observation was similar to the observation made by Bergludh et al on bone healing in 6, 8, and 12 weeks after the implantation. The site has been filled with primary and secondary osteons and marked signs of remodelling.[30]

The levels of the bone retained against the implant were different in each implant type. Despite implants were placed in the same animal and were adjacent to each other and submerged, TN implants had shown lowest bone marginal bone level than the micro-textured implants. The number of the sample size was too small to carry out any statistical evaluation. Further more the values of MG were less than the MT implants.

As bone biology tells us that the bone is an active connective tissue where it is continuously undergoes remodelling.[31] The concept of bone remodeling has been based on the theory that was proposed more than a hundred years ago. The Wolff's Law states that the remodeling of the bone is depended on the pressure derived from the use and disuse of the bone. [31] The remodeling of the bone requires certain quantity of pressure. The current belief on the bone remodeling is that the changes in the strain or pressure on the bone affect the fluid flow movements within the fine canalicullar where its increase and decrease of the flow strain stimulates osteoblast and osteoclasts.[32] Therefore on reduction in stress or excess loading on an implant that will cause micro-cracks, will both reduce fluid flow and result in the bone resorption.

This applies to the turned neck implants where under stimulation on these surfaces has resulted in bone resorption but excess loading has created bone loss.[13, 33] A loading of surrounding bone but avoiding high stress peak was suggested by Hansson et al.[34] In Hansson (1999) evaluated the level of stress on an implant using a finite element analysis (FEA) had shown to reduce the peak interfacial shear stress caused by a standardized axial load.[18]

The micro-grooves have been examined from tissue response reaction to different surface topography. Chehroudi et al had found that epithelial tissue and connective tissue react differently on micro-grooved titanium surfaces.[35] It has been shown that with micro-grooves greater than 10µm in horizontally orientation had inhibited the epithelial down growth. This was further confirmed by the same authors, using various sized grooves at 19, 30µm and 120µm pit have observed the connective tissue attachments after one and two stage implant procedure.[36] Inhibition of epithelial down growth was noted again and the changes in the orientation of fibroblasts were noted that they had a complex pattern in

comparison to the smooth surfaced titanium. Where micro texture may provide better design for tissue attachments to the implant could be considered.
There have been article which argues otherwise. Abrahamsson et al looked at the soft tissue attachment between the healing abutments with turned surface or rough surface in an animal model, he and his colleagues found that the roughness had no effect on the soft tissue attachments.[37]
When Frenkel et al had compared the bone growth over the smooth surface, micro-grooved surface and micro-grooved with growth factor, the latter two had significantly greater mechanical failure strength.[19] Ricci and his colleagues have looked at the both soft and hard tissue reactions in both in vivo and in vitro tests on micro textured surface with laser.[20]
The cell culture tests had shown faster growth rate on the micro-grooved surfaces. With bone tissue, the scanning electron micrograph had shown the orientation of the tissue was parallel to the direction of the grooves and the shear strength tests on the bone attachments to the grooves were greater than the smooth surface. In this study the orientation of the fibroblasts and the osteoblasts were difficult to notice but MG had more bones retained at the marginal bone level.
The soft tissue response from Chechroudi et al was similar to the ones observed in this study but there were some what clear collagen orientations of vertical, parallel and circumferential could be seen in some of the specimens. Also an interesting finding in MT was that the surface roughness is 1.3µm but the MT pitch was in 400µm. In close observation on the proportions where attached by soft tissue, they were lined parallel or slightly oblique to the surface. This however created an illusion of collagen orientation of perpendicular to the long axis of the implant. No such an observation has been reported in the journals as known to the author. It will be interesting to find if this alignment of collagen has any affects on the tissue attachment and its property.

The reaction by the soft tissue over MG seems to be more favourable than other surfaces. Both MG and MT values were similar but better than the TN values were noted. Some authors had cautioned for a greater gain may be seen with improvement in surgical routine.[38]

The soft and hard tissue reactions, however favoured implant with retention features. Further longitudinal clinical studies with connection with abutments to oral cavity and loading on micro-textured implants are recommended.

5. Conclusion

This is animal study which looked at the marginal bone level and the soft tissue reaction between different implant systems with various neck designs but with no long term clinical study.

Within the limitation of animal study following statement can be concluded;

1. A clear morphometric differences in the bone area could not be noticed between MT and MG implant neck types.
2. The BIC in MG implants were slightly higher than corresponding healing times of MT and TN implants. Higher values of the BIC could be measured in week 12 specimens than in week 8 specimens.
3. In the marginal bone level there was marked lowering with the TN implants and least with MG implants from the ideal marginal bone level. There was higher marginal bone levels in week 12 than week 8 in MT and MG implants specimens but not much difference in TN implant specimens.
4. With MT and MG implant surfaces, the collagen alignments were not parallel to the long axis of the implants.

The MT and MG implants, especially MG implants had advantageous tissue response in comparison to the turned neck implants.

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국 문 요 약

성견에서 임플란트 경부설계가 변연골에 미치는 영향

현재 사용되고 있는 임플란트의 문제점중의 하나는 기능 하중이 가해 진 후 일정 기간동안 변연골 소실이 발생한다는 것이다. 이의 원인을 규명하고자 연구가 지속되고 있다. 최근 임플란트의 디자인 또는 표면거칠기를 변형하고자 변연골 소실을 방지하고자는 노력이 진행되고 있다.

본 연구에서는 임플란트 경부 디자인의 변형이 변연골에 미치는 영향을 규명하고자 전통적인 Brånemark 임플란트와 경부에 micro-thread 또는 micro groove 를 설계한 임플란트를 사용하여 주위 변연골 조직을 조직형태 계측학적으로 비교해 보았다.

네마리 잡견에서 소구치를 발치하고 3 개월간 치유기간을 거친후 3 종류의 임플란트를 재조회사의 지시에 따라 식립하였다. 이중 두마리는 8 주후에 나머지는 12 주 후에 희생시켜 조직시편을 제작하여 광학현미경으로 관찰, 계측하였다. 각 임플란트는 모두 성공적으로 osseointegration 되었으며 Micro-grooved 를 가진 임플란트(MG)에서는 0.40mm, 0.26mm, micro-thread 를 가진 임플란트(MT) 에서는 0.79mm, 0.56mm, 그리고 Brånemark 형태의 turned neck 임플란트(TN)에서는 1.61mm, 1.63mm 등 세가지 임플란트 경부 부위골 소실을 볼 수 있었다. MT 임플란트와 MG 임플란트 시편에서는 TN 임플란트와 달리 더 복잡한 연조직 배열구조를 관찰할 수 있었다.

결론적으로 micro-groove 를 가진 임플란트에서 가장 적은 양의 경부 골 변화와 turned neck 에서 가장 많은 양의경부 골 변화를 볼 수 있었다.

그리고 경부설계를 달리 했을 경우에서는 연조직의 변화도 볼 수 있었다.

핵심되는 말 : 미세구조, 변연골 소실, 임플란트 설계