Original Article

# Effect of Anti-rotational Design and Counter-torque Device on Peri-implant Bone Stress During and After Preload – A Preliminary Results

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## Abstract

***Purpose:*** *Tightening an abutment screw (preload) may cause implant deformation and induce peri-implant bone strain. Preload may also transmit the torque to the peri-implant bone. This study's aims were to evaluate whether an anti-rotational design at abutment-implant interface and the application of a counter-torque device during preload would affect the transmission of torque and the development of peri-implant bone strain.* ***Materials and Methods:*** *A MirusCone abutment (MC) with an anti-rotational abutment-implant design and its configuration counterpart, without an anti-rotational design, Multiunit abutment (MU) were used for testing. The abutment screw of each type was tightened, with or without the counter-torque device application (wct and woct, respectively), by an electronic torque controller with 20 N-cm torque. During preload, the torque transmitted to implant-bone interface was measured by a torque gauge grasping the implant replicas (Nobel Biocare) for each group (MCwct, MCwoct, MUwct, MUwoct). The strain on the implant replica resulted from the clamping force of preload was measured from a snacked delta rosette strain gauge bonded on an implant replica embedded in an epoxy resin block. The outputs from the strain gauge were analyzed with Spike 2 software. The magnitude ( $\mu$ ) and direction of maximum principle strain (MPS) were calculated according to the formula provided by the manufacturer.* ***Results:*** *Application of a counter-torque device diminished about 90% of the torque transmitted to the torque gauge in both MC and MU abutments. There was no significant difference in the torque transmitted between MC and MU abutments. There is no significant difference in MPS magnitude among the groups after the preload, I.E. MCwoct: -242.48 $\mu\epsilon$, MCwct: -231.71 $\mu\epsilon$, MUwoct: -215.95 $\mu\epsilon$, MUwct: -221.00 $\mu\epsilon$. The direction of MPS was parallel to the long axis of the implant replica in all groups.*

**Keywords:** **anti-rotational design, counter-torque device, peri-implant bone stress, preload**

## Introduction

The dental implants have been used widely in the treatment of edentulous area and the success/survival rate is more than 90%. In the presence of successful osseointegration, most complications after prosthesis insertion include screw loosening,[1-5] and loss of osseointegration etc. The factors attributing to the complications are very complex, such as misfit in the implant-abutment assembly,[6-8] screw's fatigue characteristics,[8] unfavorable stress distribution,[9] occlusal overload,[5] and occlusion scheme[10] etc.

The primary objective in tightening a screw joint is to generate an optimum preload that will maximize the fatigue life of the screw while offering a reasonable degree of protection against loosening.[3,11] Preload is what keeps the screw threads tightly secured to the mating counterpart of the screw and elongates the screw between threads and screw head.[3,8] The elastic recovery of the screw creates the clamping force that pulls the prosthesis and implant together. However, the torque applied to tighten the abutment screw may deform the implant and may be transmitted to the implant-bone interface. The consequences are peri-implant bone strain may be induced and the initially achieved osseointegration may be affected.[9]

For the Brånemark system (Nobel Biocare, Göteborg, Sweden), a counter-torque device (Nobel Biocare, Göteborg, Sweden) that limits contact and rotation between the hexagons during screw tightening was recommended to prevent the transmission of the tightening force.[5] The counter-torque device is designed to reduce the improper strain transmitting to the implant-bone interface. Lang et al[5] reported that less than 10% of the recommended tightening torque was transmitted through the implant stack when the counter-torque device was used. An average of 91% of the preload tightening torque passed through the implant stack to the implant-to-bone interface in the absence of a counter-torque device. However, the mechanism of a counter-torque device on the transmission of tightening force has not been clearly known. Recently, the original anti-rotational design at the abutment-implant interface has been neglected in most implant system for multiple implant retained prosthesis. However, it is not clear whether the anti-rotational design plays a role in transmitting the tightening torque to the implant and the bone surrounding the implant.

The number of immediate loaded implants has increased recently. Since it is critical to limit the stress transmitted to the bone during the procedure, understanding the transmission of the stress and strain during tightening the abutment screw may improve the success rate of immediate loading. Thus, this study's aims were to evaluate whether an anti-rotational design at implant-abutment interface and the application of a counter-torque device during the screw tightening procedure would affect the development of peri-implant bone strain during and after preloading the abutment screw.

## Materials and Methods

### Measurement of torque

To measure the torque transmitted to implant-bone interface during abutment screw tightening, a 5 mm diameter implant replica of Brånemark system (#31160, Nobel Biocare, Göteborg, Sweden) was grasped onto a torque gauge (6BTG, Tohnichi, Tokyo, Japan). A MirusCone abutment (MC) (SDCA425, Nobel Biocare, Göteborg, Sweden) with anti-rotational abutment-implant design and its configuration counterpart, without anti-rotational design, Multiunit abutment (MU) (#29186, Nobel Biocare, Göteborg, Sweden) were used for testing (Fig1). A 20 N-cm of torque force was applied, with or without counter-torque device, to the abutment screw of a torque controller (DEA028, Nobelpharma, Göteborg, Sweden). Therefore, four different groups were tested: MC with and without counter-torque device (MCwct, MCwoct), and MU with and without counter-torque device (MUwct, MUwoct). The tightening procedures were repeated five times for each group, and the resulting torque was recorded.

Fig. 1 Abutment-implant interface of Multiunit abutment (left) and MirusCone abutment (right); 5mm diameter implant replica (bottom).

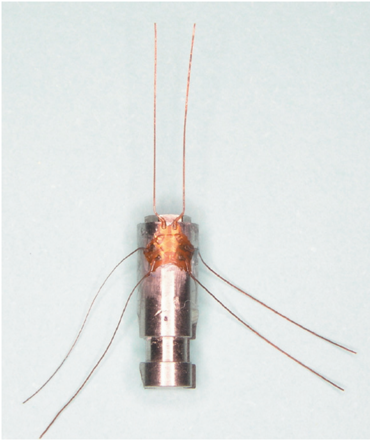


Fig. 2 A WA-06-030WY-120 strain gauge was bonded on a 5 mm diameter Brånemark implant replica.

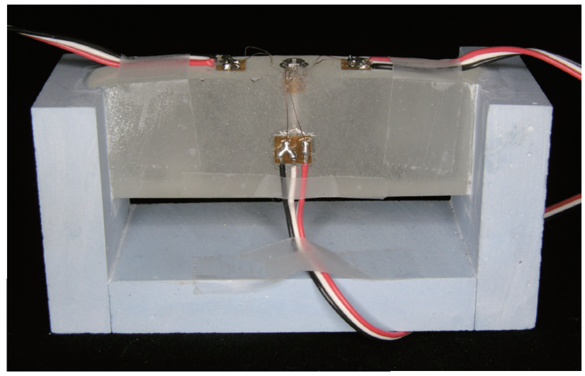


Fig. 3 The implant replica with strain gauges was embedded in a epoxy resin block.

### Construction of strain-gauge models

A rosette type strain gauge (WA-06-030WY-120, Measurement Group, Raleigh, NC) was attached onto a 5 mm diameter implant replica with M-Bond 200 (Measurement Group, Raleigh, NC). The gauge has three electrical polarized coils, and the coils are superimposed onto each other. The angle of the long axis of each coil with respect to each other is 60°. The backing of the gauge was trimmed that the center point of the coil to the abutment-implant interface was about 1.5 mm (Fig2). One of the coils, defined as SG1, had the long axis parallel to the long axis of the implant replica. The remaining two coils were named SG2 and SG3 counterclockwisely.

The implant replica with attached strain gauge was wrapped within a 12x22x70 mm epoxy resin block. Silky-Rock die stone (Whip Mix, Louisville, KY; liquid/powder = 22 ml/100g) were used to secure the resin block and hanged it in the air. This completes the construction of the model (Fig3).

### Data collection

The same dividing groups and tightening procedures as in torque measurement were followed, and the strains transmitted during and after tightening the abutment screw were recorded from the strain gauges. The signal from the strain gauges was amplified 1000 times with an amplifier (2310 Amplifier, Measurement Group, Raleigh, NC) and stored in a magnetic tape recorder (FM tape recorder, RD-145T, Teac, Japan). The signals were played back and converted (sampling rate: 1000Hz) using an analog to digital converter (A/D converter CED 1401, Cambridge Electronic Design, Cambridge, England), and then to a PC computer for analysis.

Five models were constructed and five sets of measurements from each group were obtained from each model.

### Data analysis and statistics

The rosette type strain gauge (WA-06-030WY-120) is a 3-coil electrical polarized strain gauge with permeability factor of $\epsilon_1$ 、 $\epsilon_2$ 、 $\epsilon_3$. According to the construction of the coil, the maximum and minimum principle strain ($\epsilon_{p,q}$) as well as the angle detween strain and SG1 ($\o_{p,q}$) can be obtained with the following formula provided by the manufacturer:

$$\xi_{p,q}^{\epsilon} \quad \frac{SG1+SG2+SG3}{3} \pm \frac{\sqrt{2}}{3}\sqrt{(SG1-SG2)^2+(SG2-SG3)^2+(SG1-SG3)^2}$$

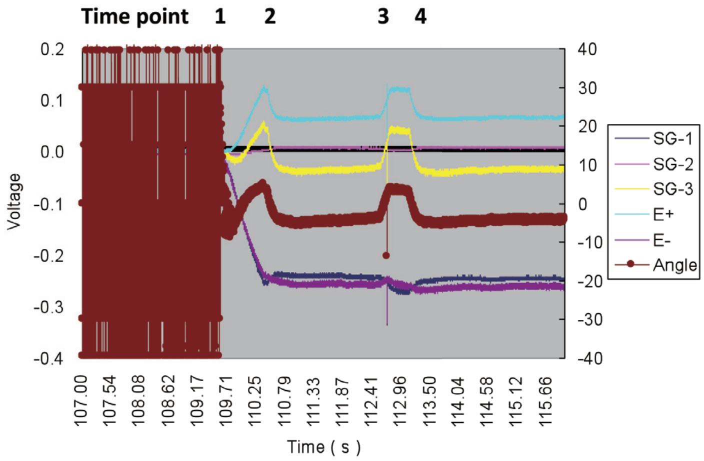
$$\phi_{p,q}^{\epsilon} \quad \frac{1}{2}\tan^{-1}\left(\frac{\sqrt{3}(SG2-SG3)}{(SG1-SG2)+(SG1-SG3)}\right)$$

The results were analyzed in steady state model known as two-way ANOVA analysis to observe statistical differences.

## Results

In the first part of our study, the abutment screw was tightened with 20 N-cm torque and the data recorded from the torque gauge represented the torque transmitted to the implant-bone interface. The average torque values were: MCwoct: 22.79 N-cm, MCwct: 2.59 N-cm, MUwoct: 22.67 N-cm, MUwct: 1.92 N-cm (Table 1). The usage of counter-torque diminished the transmitted torque to 11.4% and 8.5% in the MC abutment and the MU abutment groups, respectively. There is no significant difference in torque transmitted between the MC and MU groups disregard the use of counter-torque device.

In the second part, the values of strain gauges were stable before and after the abutment screw tightening procedures. However,




Time point 1: 1st preload, beginning of screw tightening
Time point 2: 1st preload, end of screw tightening
Time point 3: beginning of screw re-tightening
Time point 4: end of screw-retightening.

Fig. 4 Preload of the MirusCone abutment screw without applying a counter-torque device (E+ : Minimum principle strain, E-: Maximum principle strain, Angle : between the long axis of implant replica and MPS)

Table. 1 Transmitted torque (N-cm) recorded by the torque gauge from five preload trials

| | 1st | 2nd | 3rd | 4th | 5th | Mean (SD) |
|---|---|---|---|---|---|---|
| MCwoct | 22.26 | 24.32 | 22.56 | 22.26 | 22.56 | 22.79 (0.87) |
| MCwct | 2.55 | 1.86 | 2.75 | 2.84 | 2.94 | 2.59 (0.43) |
| MUwoct | 23.54 | 21.77 | 22.75 | 22.75 | 22.56 | 22.67 (0.63) |
| MUwct | 1.96 | 1.77 | 1.77 | 2.16 | 1.96 | 1.92 (0.16) |

Table. 2 The mean maximum principle strain (MPS, unit: μ ) recorded after preload

| | MCwoct | MCwct | MUwoct | MUwct |
|---|---|---|---|---|
| Model 1 | -244.65 | -208.57 | -197.40 | -234.95 |
| Model 2 | -230.93 | -201.86 | -232.19 | -219.05 |
| Model 3 | -261.24 | -273.60 | -193.97 | -211.86 |
| Model 4 | -221.38 | -219.92 | -218.22 | -220.41 |
| Model 5 | -254.20 | -254.58 | -238.00 | -218.72 |
| Mean (SD) | -242.48 (16.38) | -231.71 (31.00) | -215.95 (19.89) | -221.00 (8.48) |

Table. 3 Angle (Φ; unit: °) between the MPS and the long axis of the implant replica after preload

| | MCwoct | MCwct | MUwoct | MUwct |
|---|---|---|---|---|
| Model 1 | 4.27 | 2.99 | -10.43 | 0.55 |
| Model 2 | -5.14 | -8.42 | -10.28 | -12.80 |
| Model 3 | 0.07 | 0.08 | -11.36 | -9.49 |
| Model 4 | -5.76 | -5.87 | 12.86 | 11.72 |
| Model 5 | 6.21 | 6.51 | 15.38 | 13.65 |
| Mean (SD) | -0.07 (5.39) | -0.94 (6.17) | -0.76 (13.62) | 0.72 (11.99) |

the strain signal revealed a dynamic wave form (Fig4). The highest absolute reading value was always detected from SG1 in all groups. The data suggested that, the direction of SG1 was most parallel to the direction of principle strain. In fact, the values of SG1 were almost identical to the maximum principle strain (MPS) calculated (Fig4).

From the results of these models, there was no significant difference in the peri-implant bone strain developed after preload of the abutment screw with or without applying a counter-torque device ($P > 0.05$) and the mean strain values of the four tested groups are MCwoct: -242.48 $\mu\epsilon$, MCwct: -231.71 $\mu\epsilon$, MUwoct: -215.95 $\mu\epsilon$, MUwct: -221.00 $\mu\epsilon$ (Table 2). The data showed that preload of the abutment screw may induce peri-implant bone strain with direction close to the long axis of the implant replica in all groups (Table 3).

## Discussion

The purpose of preload is to generate an adequate clamping force which keeps two component parts together and attains stability across the screw joint. When the total external load experienced by the screw is greater than the yield strength of the screw, the protection afforded by the preload is lost and the potential for screw loosening and/or fracture occurs. Optimum preload will maximize the fatigue life of a screw and offer a reasonable degree of protection against loosening.[3,8,10]

During the process of preload, the torque may be transmitted and rotates the implant. The clamping force may also deform the implant and the excess strain could be transmitted to the implant-bone interface. Consequently, the initial osseointegration may be destroyed and the fabrication of prostheses will be delayed.[12]

Our results supported the observation of Lang et al,[5,13] when the counter-torque device was used, the magnitude of the torque transmitted to the bone was significantly reduced. Only 10 % of the tightening force was transmitted to the bone and the remainder may have been dissipated within the abutment and the counter-torque device.[5] With the application of a counter-torque device, the torque values of the MC and MU abutments were reduced to 11.4% and 8.5 % in our study. Since excess torque may cause micro-crack in the peri-implant bone, our data suggest that a counter-torque device may be needed to limit the torque if the osseointegration is compromised or an implant will be immediately loaded.

It was proposed that engaging of anti-rotational configurations between the abutment and implant can prevent rotation at abutment-implant junction and screw loosening.[6,7] However, Lang et al.[13] examined the orientation of the abutment hexagon to the implant hexagon after tightening of the abutment screw with and without the use of a counter-torque device. Their results revealed and indicated that the hexagon-to-hexagon relationship was not a major influence on the transmission of torques to the implant/bone interface during abutment screw tightening. Their results were supported by our observations that there is no significant difference in the torque transmission between an abutment with anti-rotational design (MC) and without (MU). Thus, the torque may be transferred through the contact of the screw head to the abutment screw bore. The force then may be mechanically transferred to the abutment bearing surface and, through frictional contact with the implant-bearing surface, be transferred along the implant to the implant/bone interface.

Although there was a significant difference in torque transmission between the groups using a counter-torque device and without using the device during preload, there was no significant difference in the peri-implant bone strain developed after preload ($P > 0.05$). The discrepancy may be due to measurements made at different planes by the Tohnichi torque gauge and the strain gauge. Although implant analogs were used instead of implants in our study, our data suggest that the preload may deform the implant which may induce bone strain in the surrounding bone. More research is needed to clarify whether different amount of bone strain will be induced in implants of different designs and how the bone strain may affect the osseointegration.

## Conclusions

A counter-torque device may diminish the torque transmitted to the peri-implant bone during preload. Preload may deform the implant and induce peri-implant bone strain parallel to the long axis of the implant after preload. Anti-rotational design at abutment-implant junction did not affect the torque transmission during preload and peri-implant bone strain after preload. Further studies are needed to clarity the static and dynamic changes of peri-implant bone strain during and after the abutment screw tightening procedure.

## References


1. Naert I, Quirynen M, van Steenberghe D, Darius P. A six year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism. J Prosthet Dent 1992; 67: 236-45.
2. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants 1991; 6: 270-6.
3. Haack JE, Sakaguchim RL, Sun T, Coffey JP. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants 1995; 10: 529-36.
4. Aboyoussef H, Weiner S, Ehrenberg D. Effect of an antirotation resistance form on screw loosening for single implant-supported crowns. J Prosthet Dent 2000; 83: 450-5.
5. Lang LA, May KB, Wang RF. The effect of the use of a counter-torque device on the abutment-implant complex. J Prosthet Dent 1999; 81: 411-7.
6. Binon PP. The effect of implant / abutment hexagonal misfit on screw joint stability. Int J Prosthodont 1996; 9: 149-60.
7. Binon PP. The effect of eliminating implant / abutment rotational misfit on screw joint stability. Int J Prosthodont 1996; 9: 511-9.
8. Patterson EA, Johns RB. Theoretical analysis of the fatigue life of fixture screws in osseointegrated dental implants. Int J Oral Maxillofac Implants 1992; 7: 26-34.
9. Sutter F, Weber HP, Sorensen J, Belser U. The new restorative concept of the ITI dental implant system: design and engineering. Int J Perio Resto Dent 1993; 13: 408-31.
10. Sakaguchi RL, Borgersen SE. Nonlinear contact analysis of preload in dental implant screws. Int J Oral Maxillofac Implants 1995; 10: 295-302.
11. Burguete RL, Johns RB, King T, Patterson EA. Tightening characteristics for screwed joints in osseointegrated dental implants. J Prosthet Dent 1994; 71: 592-9.
12. Ivanoff CJ, Sennerby L, Lekholm U Reintegration of mobilized titanium implants. An experimental study in rabbit tibia. Int J Oral Maxillofac Surg 1997; 26: 310-5.
13. Lang LA, Wang RF, May KB. The influence of abutment screw tightening on screw joint configuration. J Prosthet Dent 2002; 87: 74-9.