

EFFECT OF ABUTMENT DESIGN ON SCREW LOOSENING FOR WIDE DIAMETER IMPLANTS

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ABSTRACT

Purpose: Use of dental implants of various diameters and sizes has been suggested as a treatment option for implant placement into areas of reduced or limited vertical osseous height or width. The purpose of this investigation was to determine the resistance to screw loosening for three different external hexagon wide diameter implant abutment designs.

Method: Three 5.5 diameter 10 mm long implant designs (WD Lifecore implants, WP Mk II Biocare, 3i Wide Diameter) were embedded in resin blocks. Crowns, incorporating 25° cuspal inclines, were cast to fit the appropriate non-segmented machined abutments. Corresponding gold abutment screws were tightened to 32 N-cm with a calibrated ITI torque driver. Prior to fatigue loading, torques required to loosen the abutment screws were measured as baseline values. Individual crowns were subjected to simulated occlusal loadings of 6000 cycles in both clockwise and counterclockwise directions. Reverse torques to loosen the screws then were measured. Each implant type and load direction was replicated five times. Comparisons among implants and load directions were analyzed using ANOVA and t-tests with corrections for multiple comparisons.

Results: Upon counterclockwise cyclic loading, retaining screw removal torque values were lower than the clockwise loaded torque removal values. Both the baseline and counterclockwise loaded screw loosening values were higher for Lifecore than for the Biocare and 3i implants. The Lifecore loosening torque value was 18.22 ± 1.06 N-cm, compared to 14.75 ± 1.62 and 14.58 ± 0.95 N-cm for the Biocare and 3i implants respectively.

Conclusions: All implant designs tested with occlusal load clockwise loading exhibited greater resistance to screw removal torque. The Lifecore implant demonstrated a significantly higher resistance to screw removal than the 3i or Biocare implants after counterclockwise cyclic loading. Implant abutment design and occlusal loading force direction influence the degree of screw tightness and loosening.

INTRODUCTION

Screw loosening and implant failure have been found to be significant complications that may occur during the course of dental implant treatment.^{1,2} The subsequent complications from screw loosening that can ensue are screw fracture, prosthesis dislodgement, or implant failure. The relationship between a taller hexagon profile, platform diameter and an better capacity to resist screw loosening upon loading has been previously suggested.^{3,4}

The availability of implants sized to facilitate location and placement considerations have resulted in implants of both the wide and narrow size configurations. The effect of these different sized implants and their biomechanical differences in use has been discussed and evaluated.⁵⁻⁷ Wider diameter implants were suggested to provide both greater surface area for bone integration, as well as a superior abutment configuration to improve prosthesis stability and resistance to dislodgement.³

Several studies have examined the various factors and relationships involving implant retaining screw dislodgement and loosening.^{3,5,6,8,9} Other corollary investigations have evaluated the stress distribution effects of the different designs and functional applications. Stress observations using the photoelastic method have shown higher stress concentrations with non-vertical loadings compared to verticalized implant stress loads.¹⁰ Histologic and retaining screw evaluations have not shown to be clearly affected by non vertical implant angulations.¹¹

One test parameter of the significance of abutment design and the potential relationship to functional performance is the resistance of an abutment retaining screw to dislodgment. Breeding *et al* compared internal and external hexagon implant abutment designs under cyclic loading and demonstrated a decrease in screw torque values for the external hexagon implant compared to the internal hexagon implant design.⁸ Son *et al* compared the screw torque removal values for the Morse taper press-fit abutment design (ITI) to the external hexagon design and demonstrated significant higher values for the Morse taper design.⁹ The quality of fit and adaptation of components has been demonstrated to also affect screw joint stability.¹²

The effect of implant diametric platform width has been evaluated for screw joint stability. In evaluating the effects between a wide and regular standard sized implant,

Hoyer *et al* measured differences at the implant abutment interface based upon joint opening following dynamic loading conditions.⁵ Greater differences between laboratory altered implant components were found than differences between sizes and designs and of implants tested.

Comparison of the implant abutment design differences have been evaluated using a variety of techniques. These techniques have included removal modification of the external hexagon, hexagon alteration and specified comparative designs. Cirbirka, et al evaluated the effect of the external hexagon component to implant abutment design using cyclic loading prior to screw removal.⁶ They determined that hexagon removal did not affect the screw removal values for the groups tested.

Boggan evaluated the effect of prosthetic table width on retaining screw stability and strength for 4.0mm and 5.0mm diameter implants.⁷ The wider 5.0 mm diameter implant demonstrated greater resistance to compressive load compared to a 4.0 mm diameter implant.

The merits and considerations for gold or titanium abutment screw use has been reported by Binon.³ Basic comparative evaluations of screw materials relative to the different implant designs remains limited within each implant companies own proprietary system design. The design variables of each proprietary system design greatly varies. Son, et al (2001) also tested the effects of implant abutment design and the use of either gold or titanium screws for screw removal after cyclic loading for and external hexagon compared to an internal press fit implant system.⁹ A higher screw removal values was found for the gold compared to the titanium screw, and the internal press-fit abutment design implant compared to standard external hexagon design implant.

Several designs of wide diameter threaded dental implants are available. The external hexagon configuration of these implants are dissimilar in height and diameter. In addition, the retaining screw design is also dissimilar. The heights of the external hexagons for various wide diameter implants vary from 0.7 to 1 mm. Branemark had proposed that a higher external hexagon profile may improve the resistance to functional stress and screw loosening.⁴ The purpose of this investigation was to determine the resistance to screw loosening for three different external hexagon wide diameter implant abutment designs.

MATERIALS AND METHODS

Three external hex implant systems (5.5 x 10 mm WD Lifecore implants self tapping, 5.5 x 10 mm WP Self-tapping Mk II Biocare, and 5.5 x 10 mm Wide Diameter Implant, 3i) were selected for this study (**Figure 1**). Implants of each type were imbedded in blocks of photoelastic resin (PL-2, Measurements Group, Raleigh, NC). Crowns, incorporating 25 degree cuspal inclines (**Figure 2**), were cast to fit the appropriate non-segmented machined abutments (AurAdapt DCA 1086 for 5.5 mm implant, Lifecore WD 5.5 mm L2508-60-00, 3i Wide Diameter, WGA51C) (**Figure 3**).

With the blocks supported in a vise, the corresponding gold abutment screws were tightened to 32 N-cm with a calibrated torque driver (ITI torque control device, Straumann Co., Waltham, MA). Prior to fatigue loading, reverse torques required to loosen the abutment screws were measured as baseline values. Individual crowns were subjected to simulated occlusal loading of 6000 cyclic loadings (12 cycles/minute) with 5 lb weight in both clockwise and counterclockwise directions. The reverse torques to loosen the screws then were measured. Each implant type and load direction was replicated five times. The gold screw was replaced after each load cycle. Comparisons among implants and load direction were analyzed using ANOVA and t-tests with corrections for multiple comparisons.

RESULTS

The Lifecore baseline loosening torque value (20.82 ± 0.61 N-cm) was higher than the 3i or Biocare wide diameter implants. The loosening values for the 3i and Biocare implants were 17.35 ± 0.0 N-cm, and 17.53 ± 0.17 N-cm respectively. The comparisons of these findings were significant at $p < 0.0001$ (**Figure 4**).

The loosening torque values between the different implants after clockwise cyclic loading were 18.39 ± 0.73 N-cm, 18.39 ± 1.43 N-cm, and 19.95 ± 1.37 N-cm for the 3i, Biocare and Lifecore implants respectively (**Figure 5**). There were no statistically significant differences between these values ($p > 0.05$).

The counterclockwise loosening torque values were higher for Lifecore than for the Biocare and 3i implants (**Figure 6**). The Lifecore value was 18.22 ± 1.06 N-cm,

compared to 14.75 ± 1.62 and 14.58 ± 0.95 N-cm for the Biocare and 3i implants respectively. After cyclic loading, counterclockwise torque values measurements were lower than the clockwise measurements

The three implants exhibited different effects from the cyclic loading. The sequence of mean removal torque values from baseline to clockwise cyclic loading demonstrated an increasing value for the 3i and Biocare implants. The comparison of 3i baseline removal torque value to the clockwise removal torque value was found to be significant at $p \leq .02$. The comparison of Biocare implants baseline value to clockwise removal torque was not statistically significant. The comparison of Lifecore wide diameter implant baseline value to clockwise removal torque, while demonstrating a slight decrease in mean removal torque values, was not statistically significant.

The comparison of mean baseline removal torque values before and after counterclockwise cyclic loadings showed decrease after loading for the 3i, Biocare and Lifecore implants. The statistical comparison of findings demonstrated significance for baseline to counterclockwise values for the Biocare implant significant to $P \leq 0.02$.

The mean counterclockwise measurements were also lower than the clockwise measurement values found for all implants tested. The counterclockwise measurements for the 3i, Biocare and Lifecore implants were 14.58 ± 0.95 N-cm, 14.75 ± 1.62 N-cm, and 18.22 ± 1.06 N-cm respectively. The Lifecore loosening torque value in both baseline and counterclockwise measurements demonstrated a higher resistance, loosening torque value than both the 3i and Biocare implants.

DISCUSSION

The effect of abutment design on the loosening of the retaining screw was demonstrated to be different for the three-implant designs evaluated. While these proprietary designs evaluated vary in external hexagon heights and circumferences, the change in loading position was statistically significant for the resistance to cyclic loading for the three implant designs tested. Figure 7 summarizes the removal torque measurements for the three implant designs as a function of cyclic impact loading onto a clockwise or counterclockwise occlusal position in relation to a clockwise tightened retaining screw.

The height of the 3i and Biocare external hexagons are 0.6 mm and 0.7 mm, respectively. The height of the Lifecore external hexagon is 1.0mm. The diametric sizes of the external hexagons vary and are 3.3mm (Lifecore), 2.7 mm (3i), and 3.35mm (Biocare) respectively. Due to possible variations in specific materials, designs and fabrication protocols, no exact distinction of the effect of hexagon height and length is offered beyond proprietary comparisons of relative height of the external hexagon.

The comparison of the three wide diameter implants evaluated was significant for both examination of baseline screw removal torque values prior to cyclic loading and screw removal torque values after clockwise and counter-clockwise loadings. The Lifecore implant demonstrated higher resistance to removal torque of the retaining screw compared to both 3i and Biocare implants for the baseline, and counter-clockwise measurements.

Observations of the clockwise and counterclockwise measurements demonstrated higher removal torque. These values for all implant systems was observed to be higher with clockwise cyclic loading. The implied observation is the clockwise loading was observed to affect the resistance to removal torque values in a positive manner. The counterclockwise loading demonstrated a greater negative effect upon the removal torque values. The Lifecore implant demonstrated a higher resistance to the removal torque values prior to and after counterclockwise cyclic loading.

The comparison of a wide diameter implant retention screw measured removal torque was demonstrated to be between 14 to 20.8 N-cm. Son et al (2001), using the same experimental design and materials, demonstrated screw retention values for regular diameter (4.0 mm) implants of 11.71 to 13.01 N-cm for titanium retaining screws and 19.52 – 20.39 N-cm for gold retaining screws.⁹ The values demonstrated for the wide diameter implants may be considered similar to those found for regular diameter 4.0 mm (3i, Osseotite) implants.

The clinical implication of the results is that the position of occlusal contacts with screw-retained restoration may affect retention and stability of retaining screw under function in a clinical setting.

CONCLUSIONS

Cyclic loading coincident with the rotation of a retaining screw demonstrated equal or higher retaining screw removal values compared to the values prior to cyclic loading. There were no differences between implants tested.

Cyclic loading counter to the rotation of the retaining screw demonstrated lower values of screw removal compared to the baseline values prior to cyclic loading for all implants tested. The Lifecore implant demonstrated a higher resistance to screw removal after counter-clockwise cyclic loading than the 3i or Biocare implants.

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