Comparison of Secondary Stability Between Aggressive and Non-Aggressive Threaded Dental Implants in the Posterior Mandible Using ISQ: A Randomized Controlled Trials

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Abstract

This study evaluated the primary stability and changes in dental implant stability over the first eight weeks of healing in two implant types, BL and BLX, with different macro-design features, including thread geometry and self-tapping capabilities. A total of 30 patients with healed edentulous sites were randomly assigned to two groups. The test group received implants with an aggressive thread design (BLX Straumann®, Switzerland). Conversely, the control group received implants with a non-aggressive thread design (BL Straumann®, Switzerland), with 15 implants in each group. Implant stability was measured using the Implant Stability Quotient (ISQ) on the day of surgery (immediately after implant placement) and two months later. The results indicated that implants with an aggressive thread design demonstrated a higher ISQ value (74.23 ± 5.31) compared to those with a non-aggressive thread design (72.23 ± 6.65). Nevertheless, this difference was not statistically significant ($p = 0.371$). However, at the secondary stability phase, evaluated at eight weeks, non-aggressive thread implants exhibited significantly greater stability (75.87 ± 2.99) than aggressive thread implants (72.73 ± 4.85), with a statistically significant difference ($p = 0.042$). These findings suggest that while both implant types show similar early stability, further studies with extended follow-up periods are needed to assess long-term implant stability accurately. The enhanced stability of non-aggressive thread implants observed at eight weeks may indicate favorable bone-implant interactions, but conclusions regarding long-term stability cannot be made based on two months of observation.

Keywords: *dental implant, aggressive thread implant, non-aggressive thread implant, implant stability, Implant Stability Quotient values*

1. Introduction

Dental implants are widely accepted as a reliable option for tooth replacement, with high success rates reported in systematic reviews (Buser et al., 2012; Hjalmarsson et al., 2016; Howe et al., 2019). The success of dental implants relies on several factors, with osseointegration being a crucial determinant, particularly before prosthetic loading (Buser et al., 2012; Hjalmarsson et al., 2016). Branemark's pioneering work on the direct integration of bone with a titanium implant surface has been fundamental to the development of modern dental implants (Branemark et al., 1977).

Achieving sufficient primary stability is necessary to prevent micromovements that could hinder osseointegration (Koyama et al., 2011). Primary stability, which refers to the mechanical engagement of the implant with the surrounding bone, is influenced by factors such as bone density, surgical technique, and implant design (Choi et al., 2011; Resnik, 2021). As healing progresses, primary stability gradually decreases while secondary (biological) stability increases (Choi et al., 2011; O'Sullivan et al., 2004). Implant stability can be assessed at various times after placement to monitor the healing process (Su et al., 2020).

To improve osseointegration, various implant materials and designs have been developed (Albrektsson et al., 1981; Natali et al., 2009), including the aggressive-thread titanium-zirconia BLX® implant (Straumann AG), featuring a Ti-Zr (Roxolid) core and two-sided cutting progressive threads. These implants are claimed to offer superior primary stability and enhanced healing potential (Fromovich, 2019). The BLX® implant design incorporates several unique features, including thread geometry and self-tapping capabilities, which may influence implant stability.

Resonance frequency analysis (RFA) is the most widely used method for evaluating dental implant stability. It is a non-invasive technique that does not cause any damage to the implant (Lee et al., 2020a; Lee et al., 2020b).

The BL implant (Straumann AG), a widely studied bone-level implant, serves as the standard for comparison in this study. It has a well-documented clinical history and established secondary stability, making it a suitable benchmark for evaluating the BLX implant's performance (Lopez et al., 2016; Vouros et al., 2012). However, research on the BLX implant remains limited, and no studies have directly compared its secondary stability to that of BL implants.

While previous research has confirmed the relationship between macro-design and primary stability and between micro-design and secondary stability (Alzoubi et al., 2024; Lozano-Carrascal et al., 2016; Vollmer et al., 2020), limited research has compared the secondary stability of BLX implants with BL implants. Therefore, this study aims to compare changes in secondary stability between aggressive-thread titanium-zirconia implants (BLX) and nonaggressive thread design implants (BL) using the Implant Stability Quotient (ISQ).

2. Objectives

This study aims to evaluate the changes in secondary stability between aggressive-thread titanium-zirconia implants (BLX) and nonaggressive bone-level implants (BL). Specifically, it will compare the impact of thread geometry, depth of thread, and self-tapping features on secondary stability using the Implant Stability Quotient (ISQ). The findings will help to clarify how these design features contribute to long-term osseointegration and implant success.

3. Materials and Methods

Study Design

This single-blind, randomized controlled trial (RCT) was conducted following the SPIRIT guidelines and adhered to CONSORT standards for clinical trial reporting. The study protocol received approval from the Human Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, Thailand.

Participants and Randomization

Patients with at least one missing tooth in the posterior mandible requiring implant placement were recruited for this study. Before participation, they received written and oral study details, and informed consent was obtained. The research was conducted at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University.

The inclusion criteria for this study were healthy adults (≥20 years old, ASA I or II) who had undergone tooth extraction in the edentulous area at least three months prior, with adequate bone for implantation without the need for grafting, and maintained good oral hygiene. The exclusion criteria included smoking, uncontrolled systemic diseases, impaired bone healing, and jaw pathologies. Notably, bone density and bone thickness were not used as selection factors for participants in this study.

The sample size was estimated based on the study by Velloso et al. (2019), which used the ISQ to assess the stability of 20 implants (10 implants per group). Their results showed a significant difference between the test and control groups. Therefore, in this study, the sample size was calculated using G*Power software (version 3.1.9.2; Heinrich-Heine-Universität Düsseldorf, Germany) based on an independent sample t-test. To account for potential dropouts, the calculated sample size was increased by 50%, resulting in a final sample size of 15 implants per group.

Patients were randomly allocated into two groups using block randomization. Allocation concealment was ensured, and only the researchers recorded the group assignments. The control group received bone-level cylindrical implants with non-aggressive threads with an SLA surface (BL Straumann®, Switzerland) size of 4.8x10 mm. While, the test group received tapered implants with aggressive threads with

SLA surface (BLX Straumann®, Switzerland) size 5x10 mm. Participants were blinded to the type of implant placed, and the surgeons were informed about the treatment plan at the start of the surgical procedure.

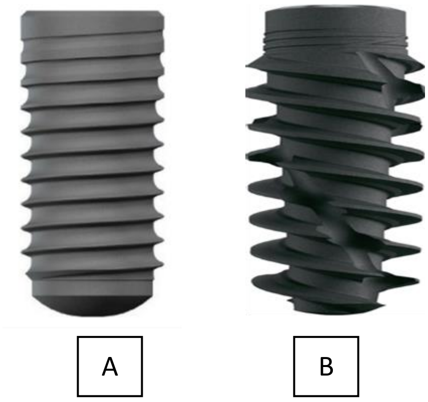


Figure 1 Images of two Straumann® implant designs. (A) Non-aggressive thread design (BL implant), and (B) Aggressive thread design (BLX implant)

Preoperative Assessment and Treatment Planning

Prior to the surgery, medical and dental history was assessed, and intraoral examination and radiographic assessments were performed. Panoramic radiographs (OPG) and cone-beam computed tomography (CBCT) using the Accuitomo 3D machine (J. Morita Inc., Japan) were used for treatment planning. To create digital planning, 3D intraoral scans were taken using the 3Shape system (Denmark). The final treatment plan was developed by an experienced oral surgeon at least two weeks prior to the procedure.

Surgical Protocol

All implant procedures were carried out by two expert surgeons using a standardized approach. Implants were placed according to manufacturer guidelines, healing abutments were attached, and soft tissues were sutured. Postoperative care included prescribed analgesics and antibiotics. After 14 days, sutures were removed, and periapical radiographs were taken. Implants with insufficient stability (MIT <25 Ncm or those covered with cover screws) were excluded from the study.

Data Collection

Demographic data and radiographic images were retrieved from the Faculty of Dentistry's database. Implant stability was assessed using ISQ values measured with Osstell® and SmartPeg® (types 54 and 38) (Osstell AB, Sweden) by a calibrated researcher. Measurements were taken immediately after implant placement and at eight weeks post-surgery.

The stability measurement using the Osstell ISQ device involved attaching a smartpeg, which acted as a transducer, to the implant. The device then emits a magnetic pulse through the probe, which is transmitted to the implant. The resulting resonance frequency was recorded as an Implant Stability Quotient (ISQ) value ranging from 1 to 100. Measurements were taken at the buccal and mesial sides of the smartpeg to assess the implant's stability.

Figure 2 Ostell device (Reprint from Osstell® company, Sweden)

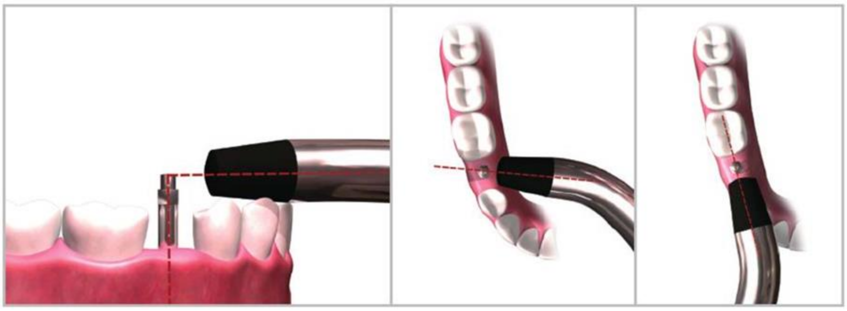


Figure 3 The image shows the measurement position of the Ostell device through the smart peg in the implant.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics software (version 28.0.0.0). The chi-square and independent sample t-tests were used for categorical and continuous variables, including ISQ values. Data distribution was assessed using the Kolmogorov-Smirnov test for normality. The level of statistical significance was set at 0.05, with a 95% confidence interval.

4. Results and Discussion

4.1 Results

A total of 30 patients who had lost their posterior teeth in the mandible and met all inclusion criteria were selected for dental implant treatment. A total of 30 implants were employed. After randomization, 15 patients were assigned to the BLX group, and another 15 were assigned to the BL group. The patient group consisted of 13 males and 17 females, with a mean age of 49 ± 13.46 years (ranging from 22 to 73 years). All implants were placed in bone without the need for augmentation procedures.

The surgeries were performed successfully without any complications. All implants received prosthodontic rehabilitation and are currently functioning with no complications or failures. There was no heterogeneity among the groups in terms of patient demographics, clinical data, or surgical procedures, as shown in Table 1

Table 1 Patient characteristics

Characteristics	BLX implant	BL implant	All	P-value
Implants, n (%)	15 (50)	15 (50)	30 (100)	-
Gender, n (%)				
Male	8 (26.67)	5 (16.67)	13 (43.33)	
Female	7 (23.33)	10 (33.33)	17 (56.67)	0.462
Age (Years), mean (SD)	46 (12.41)	52 (14.30)	49 (13.46)	0.262

At the time of implant placement, the BLX implant group exhibited a higher mean ISQ value (74.23 ± 5.31) compared to the BL implant group (72.23 ± 6.65); however, this difference was not statistically significant (p = 0.371). By the eighth week, a statistically significant shift was observed, with the BL implants demonstrating higher ISQ values (75.87 ± 2.99) than the BLX implants (72.73 ± 4.85). (Table 2 and Figure 4).

Table 2 Mean and standard deviation of ISQ values in each implant group

ISQ values	BLX implant (Mean ± SD)	BL implant (Mean ± SD)	P-value
Operation Day	74.23 ± 5.31	72.23 ± 6.65	0.371
8 weeks	72.73 ± 4.85	75.87 ± 2.99	0.042*

Table 3 shows the change in mean ISQ values between the operation day and the eight-week follow-up for the BL and BLX groups. No significant differences were observed in either the BLX implant group (p = 1.000) or the BL implant group (p = 0.274).

Table 3 The ISQ values change within the group.

ISQ values	Operation day (Mean ± SD)	8 weeks (Mean ± SD)	P-value
BLX implant	74.23 ± 5.31	72.73 ± 4.85	1.000
BL implant	72.23 ± 6.65	75.87 ± 2.99	0.274

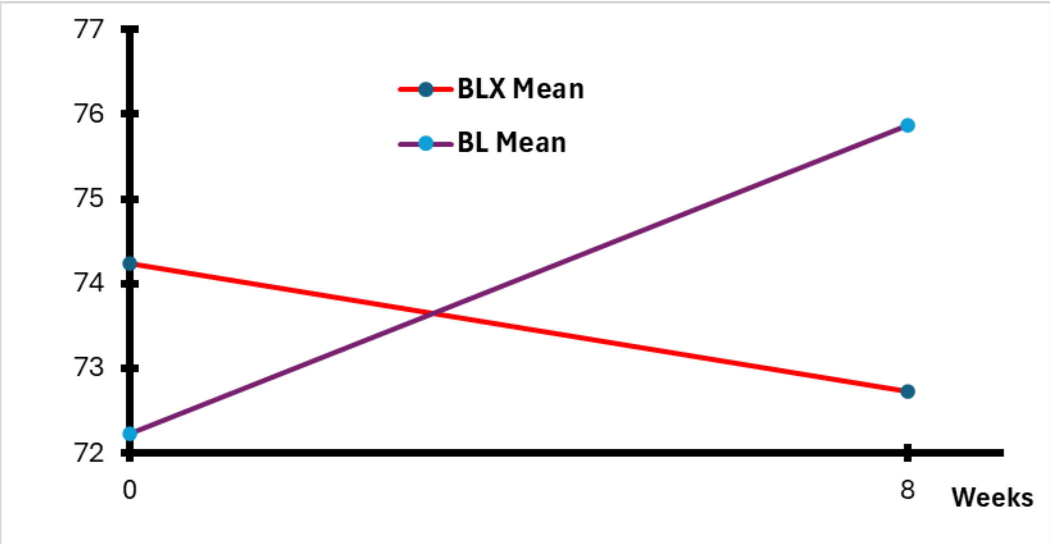
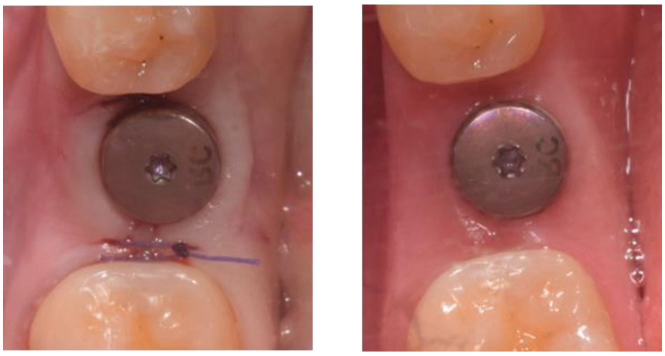


Figure 4 Mean implant stability quotient (ISQ) values for the BLX implants (red line) and BL implants (purple line). Overall assessment at the two-time observation points (n = 30).



A B

Figure 5 The area where the dental implant was placed. (A) on the day of implant placement, and (B) after 8 weeks of follow-up.

4.2 Discussion

This single-blinded, randomized, controlled trial compared the stability of aggressive-thread and non-aggressive-thread dental implants placed in the posterior mandible. The rationale for this study stems from the ongoing debate regarding the impact of implant thread design on both primary and long-term stability, especially in challenging anatomical regions such as the posterior mandible. While aggressive-thread implants, such as the BLX implants used in this study, are often considered to provide superior primary stability due to their deeper threads and larger pitch, their long-term stability remains less clear. The non-aggressive-thread implants, represented by BL implants, were selected as a comparison to explore whether they might offer advantages in terms of long-term stability.

The results indicated that although both implant types exhibited similar initial stability, the non-aggressive-thread implants demonstrated significantly higher ISQ values at eight weeks, suggesting that while both designs provided comparable primary stability, the non-aggressive-thread implants offered better long-term stability at this early time. These findings are consistent with existing research, which suggests that the initial stability provided by aggressive-thread implants may not always translate into superior long-term stability. However, it is important to note that eight weeks of observation is insufficient to conclude with certainty long-term stability, and caution should be exercised in interpreting these results as reflective of final implant success.

Regarding the influence of implant macro-design on primary and secondary stability, the results align with previous studies that highlight the complexity of these factors. Many studies have reported enhanced primary stability in aggressive-thread implants due to their deeper threads, micro-threads, or multiple threads, which typically improve both primary and secondary stability (Ibrahim et al., 2020; Quispe-López et al., 2024). Additionally, tapered implants have been shown to exhibit superior primary stability compared to cylindrical designs (Heimes et al., 2023; Herrero-Climent et al., 2020). Conversely, conflicting findings have emerged in studies comparing aggressive-thread implants to non-aggressive designs. Imai et al. (2022) and Emmert et al. (2022) found no significant differences in primary stability between aggressive-thread (BLX) and non-aggressive-thread (TE) implants, while Waechter et al. (2017) suggested that implant shape did not significantly affect primary or secondary stability. In contrast, Supachaiyakit et al. (2022) observed higher early stability in aggressive-thread implants, particularly within the first 8 weeks after placement.

In line with Trisi et al. (2015), which demonstrated that aggressive implants result in higher bone-to-implant contact (BIC), our study confirms that more aggressive thread designs may lead to larger BIC areas. However, it is imperative to recognize the potential risks of aggressive-thread implants. Excessive pressure during placement can cause microfractures and bone burns, potentially impairing bone healing

(Lemos et al., 2021). Therefore, while aggressive-thread implants may offer advantages under certain conditions, caution should be exercised during their placement to avoid complications that could negatively affect bone health.

The ISQ values observed in this study were all above 70, which is typically considered indicative of high implant stability. However, it is important to note that ISQ values alone may not provide a complete assessment of implant stability in clinical practice. While ISQ values greater than 70 are generally considered high, they should be interpreted with caution, especially when evaluating long-term outcomes. Other factors, such as bone quality and healing dynamics, play a critical role in determining the long-term success of implants, and these should be considered in clinical evaluations.

A limitation of this study is that we did not classify the bone quality at the implant site, which may have influenced the observed differences in implant stability. Bone density and quality can significantly impact the success of implant placement, and future studies should account for these variables to gain a clearer understanding of how implant design interacts with bone characteristics. Since the current study did not consider bone quality, the observed differences in stability between implant types could be attributed to variations in bone conditions at the implant sites.

Overall, this study highlights the importance of considering both primary and long-term stability when selecting implant designs. While aggressive-thread and non-aggressive-thread implants can offer similar primary stability, non-aggressive-thread implants may provide better stability in the early stages of healing. However, further research with extended follow-up periods is needed to fully assess the long-term outcomes of these two implant designs. Future studies should explore the relationship between implant macro-designs and stability in different bone conditions, accounting for both the quantity and quality of the bone. Such research will provide valuable insights into the factors affecting implant success and help guide clinical decisions based on patient-specific conditions.

5. Conclusion

The results of this study suggest that non-aggressive-thread implants demonstrated better stability at 8 weeks compared to aggressive-thread implants. However, other factors influence implant stability, including bone quality and the healing process. Therefore, caution should be taken when interpreting the study results without considering these additional factors. Further research with extended follow-up periods and diverse clinical settings is necessary to better understand the long-term outcomes of different implant thread designs.

6. Acknowledgements

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