Original Article

Comparative analysis of insertion torque and fracture resistance between two brands of infra-zygomatic crest screws

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Abstract

Objective: The present study aimed to determine the insertion torque and fracture resistance of infra-zygomatic crest (IZC) screws as critical factors influencing primary stability.

Methods: A total of 40 stainless steel IZC mini-screw implants (MSIs) were obtained from two different manufacturers (Bio-Ray, Taiwan, and S. K. Surgicals, India). Each group comprised 20 MSIs of identical dimensions (2 ×14 mm). To simulate a clinical scenario, a customized jig was utilized to embed these screws into human maxillary bone blocks for evaluation of maximum insertion torque (MIT), and into polyacrylic glass blocks for assessment of fracture resistance. A digital torque gauge was used to obtain precise torque measurements.

Results: There were significant differences in MIT between the groups at the tip and neck areas of the screws ($P<0.05$). The Bio-Ray IZC screws manifested significantly greater insertion torque at the tip and significantly lower insertion torque at the neck compared to the S.K. Surgicals group ($P<0.05$). However, the two groups demonstrated no significant difference in terms of fracture resistance ($P=0.484$).

Conclusions: The evaluated mini-implants displayed a diverse range of insertion torques at various parts of the screws (increasing from tip to mid and neck regions). It is imperative to consider various torque values during screw insertion to mitigate the risk of tissue damage and screw breakage. The present findings revealed no significant difference in fracture resistance between the two brands of mini-implants, suggesting that the fracture torque was primarily influenced by factors beyond the manufacturer of the MSIs. (J Dent Mater Tech 2023;12(2): 91-97)

Keywords: Fracture resistance, Infra-zygomatic crest, Insertion Torque, Maxillary bone, Screw

Introduction

Efficient anchorage control is a paramount component for the successful execution of orthodontic treatment, which has motivated continuous efforts to develop appropriate anchorage systems (1). Within the oral cavity, the anchorage is typically facilitated by the surrounding teeth, the palate, and soft tissues, whereas external aids, such as headgear, provide extraoral support (1). Temporary Anchorage Devices (TADs) have revolutionized modern orthodontic practice by providing reliable and precise points of absolute anchorage. These skeletal anchorage systems, including mini-plates, on-plates, mini-implants, and a variety of mini-screws, such as interradicular and zygomatic screws, are routinely employed to assist in the targeted movement of specific teeth. Each TAD is carefully inserted into the oral bone structure, allowing orthodontists to manipulate complex tooth movements more efficiently and effectively (2).

Infra-Zygomatic Crest (IZC) screws are employed as temporary anchorage devices in orthodontics. These screws are strategically placed in the IZC, a robust cortical bone pillar at the zygomatic process of the maxilla, to provide reliable and absolute anchorage during treatment (3, 4). However, despite their clinical utility, these devices can become loose, mobile, or displaced, potentially leading to damage to surrounding structures and causing complications such as inflammation or infection (5). The factors contributing to early MSI loss remain relatively obscure, necessitating further investigations.

In this context, achieving and maintaining implant stability at the insertion site is critical for successful MSI application. Primary stability is believed to be the cornerstone of effective MSI performance (6). Insertion torque, measured in Newton centimeters (Ncm), represents the rotational force needed to insert the MSI

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into the bone and serves as a valuable indicator of implant stability (7, 8).

Satisfactory insertion torque (MIT) values typically fall near the range of 35 Ncm, with such values traditionally regarded as markers of optimal MSI function (9). The angular placement of IZC screws is another factor affecting the stability of MSIs. Jariyapongpaiboon and Chartpitak (10) revealed that an insertion angle of 30˚ maximizes the primary stability and MIT of screws.

Low insertion torque increases the risk of MSI loosening at the bone interface, compromising primary stability. Conversely, excessive insertion torque surpassing the recommended range can lead to bone defects and necrosis (10). An additional consequence of high insertion torque can be a failure of the MSI due to bending. Despite the relative paucity of literature on this subject, recent surveys suggest that 10%-20% of clinicians have experienced mini-implant breakage during insertion (11).

This investigation aimed to comprehend and quantify the insertion torque and fracture resistance of two different brands of IZC screws.

Materials and Methods

The present study comprised 40 IZC mini-screws from two distinct manufacturers. The selected mini-implants were of identical dimensions, featuring a tapering shape with an outer diameter of 2 mm and a total length of 14 mm.

The IZC mini-screws were divided into two groups. One group consisted of 20 screws from Bio-Ray Instruments Co., Ltd, Taiwan, and the other group involved 20 screws from S.K. Surgicals, Maharashtra, India. Each group was subsequently divided into two equal subgroups of 10 screws each, designated for the appraisal of primary stability and fracture resistance. A digital torque gauge (series TT03, MESURR lite data acquisition software) was used to accurately record the insertion torque and peak torque value at the point of fracture.

Human maxillary bone was carefully dissected into rectangular segments extending from the second premolar to the second molar region anteroposteriorly and from the maxillary sinus base to the occlusal plane superior-inferiorly. Twenty of these segments were secured onto an acrylic block at a 30˚ angle. The IZC mini-screws were then inserted perpendicularly into these bone segments (Figure 1A).

For measuring fracture resistance, two rectangular blocks of acrylic glass (2 cm × 4 cm × 17 cm) were cut and prepared, then stabilized using an aluminum fixer (Figure 1B). The acrylic glass was chosen as a medium due to its homogeneity and optimal stiffness that allowed consistent fracture of all mini-screws (11). The fracture resistance of all IZC screws was ascertained using a digital torque gauge (Figure 1).

To ensure precise insertion torque and fracture resistance testing, a custom-made jig was fabricated. This apparatus comprised a stabilizing bar for the accurate positioning of a digital torque driver, and an aluminum fixer to secure the acrylic blocks on which bone segments and acrylic glass blocks were mounted (Figure 1). This setup facilitated the perpendicular insertion of IZC mini-screws into the cortical bone surface and acrylic glass blocks. The human maxillary bone was pre-angled at 30˚, based on a study conducted by a previous study (10), which measured MIT at this angle.

The IZC screws were meticulously inserted into the maxillary bone blocks and acrylic glass blocks in a clockwise motion by a single operator. The procedure was performed at a consistent speed of 10 to 12 rpm and was terminated when the thread of the mini-screws was entirely within the blocks, thereby mimicking clinical conditions. The MIT was logged in Newton centimeters. Peak placement torque values at the tip, middle, and neck regions were recorded during IZC screw insertion into the maxillary bone. Subsequently, IZC screws were implanted into the acrylic glass blocks, and the peak torque value at the point of fracture was recorded.

Statistical analysis

Since the collected data exhibited a normal distribution, parametric tests were deemed suitable for further analysis. An independent samples t-test was employed to compare the mean values of insertion torque and fracture resistance between the two groups. All the statistical analyses were performed using SPSS software (version 23.0, IBM, USA). A p-value < 0.05 was considered statistically significant.

Results

The results of this in vitro study revealed variations in insertion torque at different levels of the screws for both types of IZC mini-screw implants.

The mean insertion torque value at the tip level of the screw was significantly greater in Bio-Ray IZC screws compared to S.K. Surgicals IZC screws (P= 0.006; Table 1).

At the mid-level of the screw, there was no significant difference between the mean insertion torque values of the two IZC screws (P= 0.631; Table 2).

In contrast to the tip level, the maximum insertion torque at the neck level of the screw was significantly lower in Bio-Ray IZC screws compared to S.K. Surgicals IZC screws (P< 0.001; Table 3).

In terms of fracture resistance, the mean torque value at fracture was similar for both S.K. Surgicals and Bio-Ray IZC screws. There was no significant difference in fracture resistance between the two brands of IZC screws according to the statistical analysis (P= 0.484: Table 4).

Figures 1. A: A slider clamp containing bone block for insertion of the mini-screw implants (MSIs) to quantify insertion torque. B: A customized jig with the acrylic glass block to measure the fracture torque of MSIs.

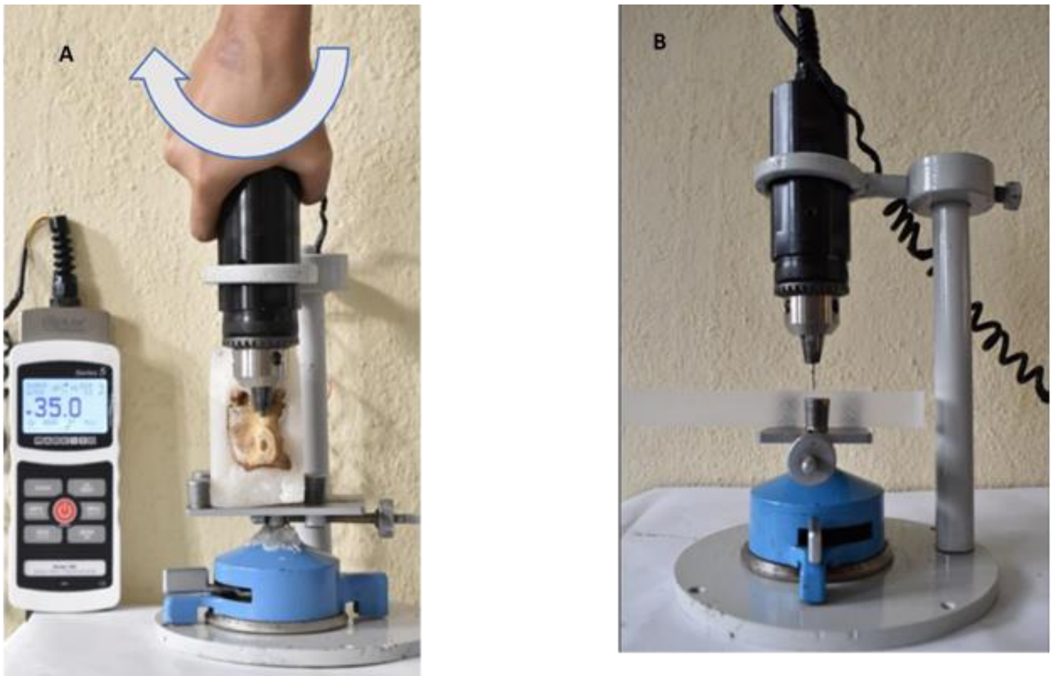

Table 1**.** Comparison of insertion torque (Ncm) at the tip level of S.K. Surgicals and Bio-Ray IZC screws placed in human maxillary bone

Group	Mean	SD	95% CI for mean		t-value	*P*-value
			Lower	Upper		
S.K. Surgicals IZC screws	13.65	2.61	11.78	15.52	-3.1360	0.006*
Bio-Ray IZC screws	17.95	3.46	15.48	20.42		

*Statistically significant differences were noted at P<0.05.

Table 2**.** Comparison of insertion torque (Ncm) at the mid-level of S.K. Surgicals and Bio-Ray IZC screws placed in the human maxillary bone

Group	Mean	SD	95% CI for mean		t-value	*P*-value
			Lower	Upper		
S.K. Surgicals IZC screws	37.00	2.97	34.87	39.13	0.4890	0.631
Bio-Ray IZC screws	35.65	8.20	29.78	41.52		

Table 3. Table 1. Comparison of insertion torque (Ncm) at the neck level of S.K. Surgicals and Bio-Ray IZC screws placed in human maxillary bone

Group	Mean	SD	95% CI for mean		t-value	*P*-value
			Lower	Upper		
S.K. Surgicals IZC screws	65.35	3.12	63.12	67.58	4.3770	<0.001*
Bio-Ray IZC screws	54.45	7.23	49.28	59.62		

*Statistically significant differences were noted at P<0.05.

Table 4: Comparison of torque value at fracture between S.K. Surgicals and Bio-Ray IZC screws placed in the polyacrylic glass block

Group	Mean	SD	95% CI for mean		t-value	*P*-value
			Lower	Upper		
S.K. Surgicals IZC screws	54.05	14.11	43.96	64.14	-0.7140	0.484
Bio-Ray IZC screws	57.30	2.79	55.30	59.30		

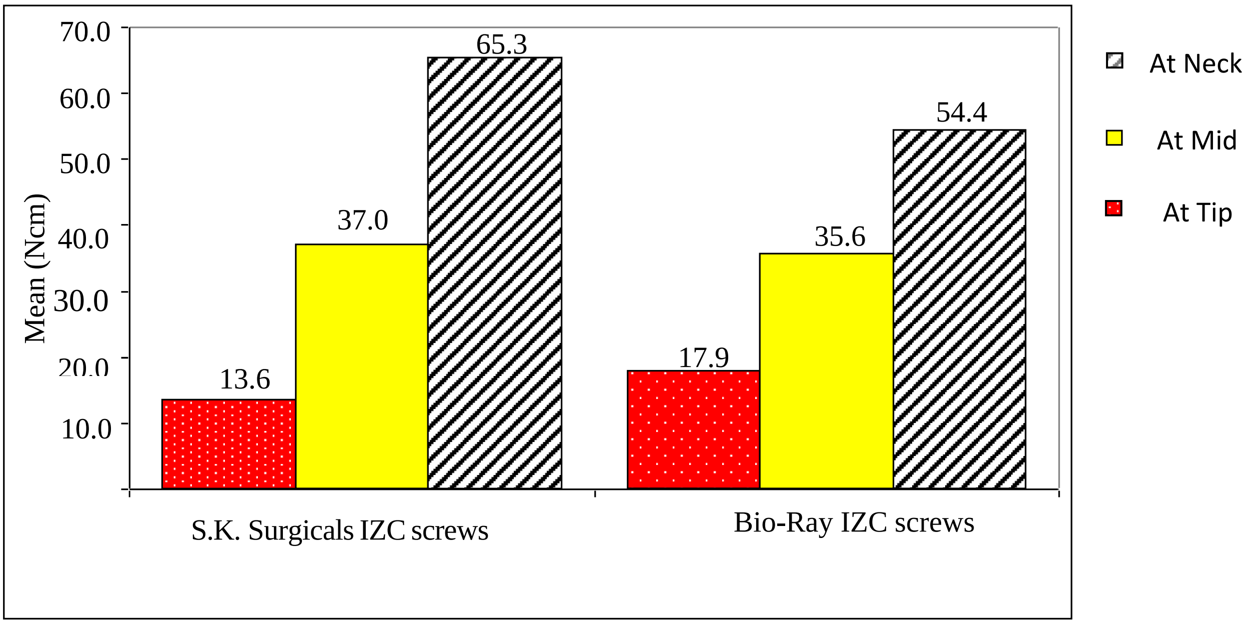

Figure 2. Comparison of maximum insertion torque values (Ncm) at different levels of S.K. Surgicals and Bio-Ray IZC screws during insertion in human maxillary bone

Both IZC screws demonstrated increased insertion torque values from the tip to the neck level during placement into the maxillary bone. The Bio-Ray mini-implants exhibited a relatively greater torque value at the tip and a lower torque value at the neck level than the S.K. Surgical screws, implying a lower percentage of increase in torque values from the tip to the neck area (Figure 2).

Discussion

Successful orthodontic treatment highly depends on the reliable establishment of anchorage. The MSIs, which are pivotal to this success, must withstand orthodontic forces throughout the entire anchorage reinforcement period. However, MSIs have been reported to have lower success rates (80-85%) compared to osseointegrated implants.

Therefore, optimizing the interface between the MSI and bone tissue is paramount in enhancing the success rate of mini-screws.

In the present study, the insertion torque of IZC mini-screws was investigated along their entire length. The results showed that the Bio-Ray mini-implants exhibited a significantly greater torque value at the tip and a significantly lower torque value at the neck level as compared to the S.K. Surgical screws, implying a lower percentage of increase in torque values from the tip to the neck area. This finding suggests that Bio-Ray IZC screws may provide a more conservative approach when interacting with the bone tissue, which could potentially influence the success rate of treatment. The greater insertion torque at the tip is beneficial in providing primary stability, whereas the lower insertion torque at the neck may improve secondary stability. It is important to address torque during mini-implant positioning to minimize the risk of tissue damage and implant fracture in high-density bone locations especially when predrilling might not be feasible.

The second phase of this study focused on evaluating the fracture resistance of IZC MSIs. To achieve this, we used a digital torque meter to measure fracture moments after insertion into acrylic glass blocks. Although it is clear that acrylic glass has different characteristics compared to human bone, this material was chosen for several reasons. Its homogeneous nature ensured the repeatability and comparability of the measurements. Moreover, the greater hardness of acrylic glass compared to bone increased its resistance to fracture, even with the insertion of MSIs with considerable length and diameter, as performed in this investigation.

In the present study, no significant difference was observed in the fracture resistance between S.K. Surgicals and Bio-Ray IZC screws, suggesting that the fracture torque was primarily influenced by factors beyond the manufacturer of the MSIs. This finding was in contrast to those of Smith et al. (12), who discovered a wide range of fracture torque in six frequently used self-drilling orthodontic micro-implants depending on the MSI manufacturer. According to Wilmes et al. (13), the diameters of the mini-implants significantly impact fracture torque values, implying that utilizing mini-implants with wider diameters might be advantageous to resist breakage.

The present study stands apart from previous studies due to the use of human maxillary bone for MSI insertion, whereas previous studies primarily used synthetic bone or animal bones. Our approach was to replicate clinical conditions as closely as possible to obtain more accurate results. To ensure a reliable replication of typical clinical scenarios, a precision mini-implant screwdriver was chosen for the placement of IZC screws into the maxillary bone. The highest placement torque, registered during the tightening of the mini-implant into the bone, was quantified at different screw levels (tip, middle, and neck) using a digital torque gauge.

MSI placement can be performed by two methods: manual insertion (utilizing a hand driver) and machine-driven insertion. Previous studies have indicated that machine-driven MSIs have a failure rate of 28%, which is significantly higher than the 11% failure rate associated with manually inserted MSIs (15). This discrepancy can be attributed to the increased frictional heat generated during engine-driven drilling, leading to extensive damage to the bone tissue and cells (16). Additionally, machine-driven MSI insertion does not offer a tactile sense of bone resistance or load application to the mini-screw implant (17). In light of these considerations, the current study favored the manual MSI insertion approach to better mimic clinical conditions.

As far as the angle of insertion is concerned, we opted for a 30° insertion angle. A previous study suggested the insertion of IZC mini-screws at a 30° angle to the buccal bone of the maxilla, as the peak insertion torque of mini-screws at this angle was significantly higher than that of other angles (10). However, the optimal angle of insertion appears to vary in different studies. For instance, Meira et al. (18) observed that a 45° insertion angle yielded the highest MIT, suggesting that mini-implants exhibited a higher insertion torque with an increase in inclination to the bone surface. Likewise, Araghbidikashani et al. (19) discovered that mini-screws subjected to shear force exhibited greater primary stability values at a 45° angle and a 90° angle when a pullout force was applied. In contrast, Wilmes et al. (20) reported that a 70° angular insertion produced greater MIT than angles of 30°, 40°, 50°, 60°, or 90°.

Overall, the present findings provided a detailed comparison of insertion torque and fracture resistance between S.K. Surgicals and Bio-Ray IZC screws, offering valuable insights for their clinical application in orthodontics. The intricacy of the factors influencing the insertion torque and fracture resistance of MSIs indicates the need for further research in this domain.

The present study focused on the insertion torque and fracture resistance of IZC screws. However, numerous factors influence the success rate of mini-screw implants and were not considered in this study, such as the quality and quantity of surrounding bone, oral hygiene, force magnitude, direction and duration of force, screw design, and operator skill. The number of samples used in this study was relatively small. Clinical studies with a larger sample size could provide more robust data and assess the statistical significance of other factors influencing the success and survival rate of mini-implants.

Conclusions

Considering the limitations, the conclusions drawn from the present study are listed as follows:

1- The Bio-Ray IZC screws manifested significantly greater insertion torque at the tip and significantly lower insertion torque at the neck compared to the S.K. Surgicals group. This finding suggests that Bio-Ray IZC screws may provide a more conservative approach and provide higher stability, which could potentially influence the success rate of treatment

2- In terms of fracture resistance, the mean torque value at fracture was comparable for S.K. Surgicals and Bio-Ray IZC screws, suggesting that the fracture torque was primarily influenced by factors beyond the manufacturer of the MSIs.

Conflict of Interest

None to disclose.

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