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Research Article

Does Increased Cortical Screw Adhesion on the Far Cortex Result in Higher Resistance against Pull-Out?

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Abstract

Aim: Cortical screws exert compression on the fracture line by applying pressure to the surrounding cortex, while the screw moves within the bone structure through the threads as a result of cyclic movement. To achieve this compression, the cortical screw threads must adhere to the far cortex. The aim of this biomechanical study was to biomechanically evaluate the effect of varying degrees of contact with the far cortex on the resistance against pull-out and to determine the ideal amount of cortical adhesion.

Material and Method: A biomechanical study was conducted on the diaphyseal portions of 12 synthetic femur bones without the formation of any fracture models. The synthetic bones were initially divided into three groups, as follows: partial contact with the far cortex, full contact with the far cortex, and passed through the far cortex. The prepared models were subjected to testing, and after the bone was affixed within the compression device, the head of the screw on the bone was grasped with the aid of a tool, and a tensile force was applied to the cortical screw head until pull-out (load to failure).

Results: A significant difference was observed when the pull-out strengths were compared between groups (p=0.021). Post-hoc analyses revealed that this statistical difference was due to the group in which at least three threads passed through the far cortex.

Conclusion: When choosing the cortical screw length, a stronger pull-out resistance can be expected with a longer cortical screw length and passing the distal end through the far cortex. However, this should be decided taking into account the characteristics of the anatomical region to be treated, the nearby neurovascular structures, and the risk of tendon-soft tissue irritation.

Keywords: Biomechanical study, cortical screw, far cortex adhesion, fixation strength, pull-out

INTRODUCTION

Screws are a versatile and reliable choice for fixation in the field of orthopaedics and traumatology due to their ability to convert rotational force applied to them into linear motion through the use of threads. They can be classified according to the external diameter of their threads (cortical-cancellous), according to the existence of threads in the screw head (locking screws), or according to their applications (plate screws, lag screws, position screws, polar screws, etc.) (1-3). Cortical screws are one of the most commonly utilized screws in the field of traumatology. Through the threads, the screw head exerts compression on the fracture line by applying pressure to the surrounding cortex, while the screw moves within the bone structure as a result of cyclic movement. To achieve this compression, the cortical screw threads must adhere to the far cortex (4). This adhesion can be achieved to varying degrees with different screw lengths. Depending on the preferred screw length, compressive strength can be achieved with varying degrees of contact with the far cortex or with screws long enough to pass through the far cortex. It is essential that adequate compression strength is achieved for fracture healing, as inadequate retention may result in pull-out (screw retraction and loss of fixation).

It is regrettable that the desired screw lengths may not always be available due to limitations such as material supply issues or patient anatomical differences. Furthermore, the passage of the screw through the far cortex may give rise to soft tissue complications. To date, to the best of our knowledge, several studies in the

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literature have investigated cortical screw pull-out risk factors (5-9). However, no studies have investigated the relationship between varying degrees of contact to the far cortex and resistance against pull-out.

The aim of our study was to biomechanically evaluate the effect of varying degrees of contact with the far cortex on the resistance against pull-out and to determine the ideal amount of cortical adhesion.

MATERIAL AND METHOD

A biomechanical study was conducted on the diaphyseal portions of 12 synthetic femur bones without the formation of any fracture models (Third Generation Composite Left Femur; Selbones, Kayseri, Türkiye). The synthetic bones were initially divided into three groups, as follows: partial contact (Group 1), full contact (Group 2), and passed through (Group 3). The bones in Group 1 were inserted with cortical screws to achieve partial contact with the far cortex. In Group 2, cortical screws were inserted to achieve full contact with the far cortex. In the final group (Group 3), cortical screws were inserted with a length that ensured at least three threads at the distal end of the screw passed through the far cortex and exited from the opposite side (Figure 1). All synthetic bones were pre-drilled with a 3.2 mm cortical screw drill and then fixed to the bone with a 4.5 mm fully threaded cortical screw (TST Orthopedics®, TST Medical Tools®, İstanbul, Türkiye). The screws were 40 mm, 42 mm, and 44 mm in length, respectively, and were fixed in place with a screwdriver. All drilling and screwing procedures were conducted in the same anatomical location of the synthetic bone, in the midline of the diaphyseal region.

The prepared models were subjected to testing in the Marmara University Department of Mechanical Engineering (İstanbul, Türkiye) testing laboratory, utilizing the axial compression device (Shimadzu MWG-50 kNA Tensile Testing Machine, Shimadzu Company®, Kyoto, Japan). With the installed system (Figure 2), the bone was affixed within the device, the head of the screw on the bone was grasped with the aid of a tool, and a tensile force was applied to the cortical screw head until pull-out (load to failure). The applied forces were recorded in real time using the device's integrated software. In calculating the pull-out strength, the initial pull-out was defined as the moment when the resistance was first broken and the force-displacement curve first changed direction (Figure 3). Secondary resistances that may occur due to remaining threads in the cortex after the initial pull-out of the screw were not considered in this analysis. The experiment was repeated for each bone model in sequence, with the results recorded.

The data were analyzed statistically using the SPSS software. The conformity of the data to a normal distribution was assessed both visually (histogram and probability plots) and analytically (Kolmogorov-Smirnov test). Given that the data were skewed distributed, a Kruskal-Wallis test was employed for three-group comparisons and a Mann-Whitney U test for post-hoc pairwise analyses. The median and minimum-maximum range values were used for descriptive statistics. Statistical significance was defined as a P value less than 0.05.

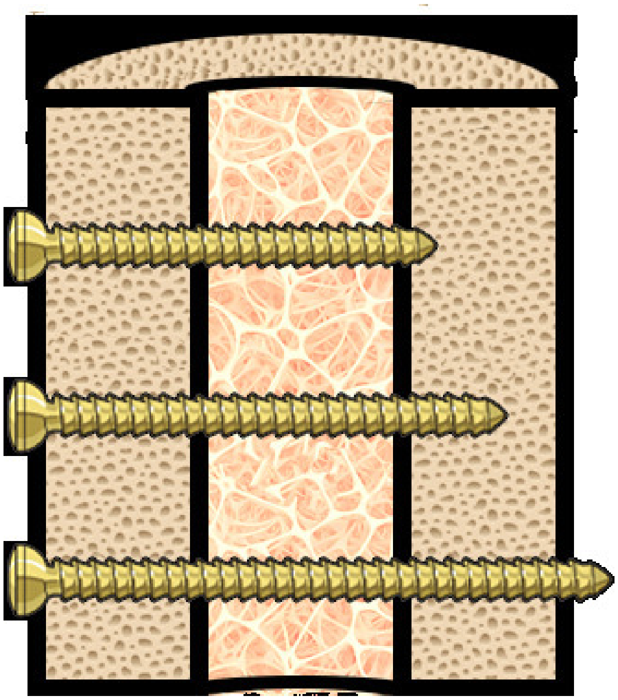

Figure 1. The illustration depicting the configuration of experiment groups. The upper screw represents Group 1, which demonstrates partial contact with the far cortex. The middle screw represents Group 2, which demonstrates full contact with the far cortex. The lower screw represents Group 3, which demonstrates at least three drilled threads passed through the far cortex

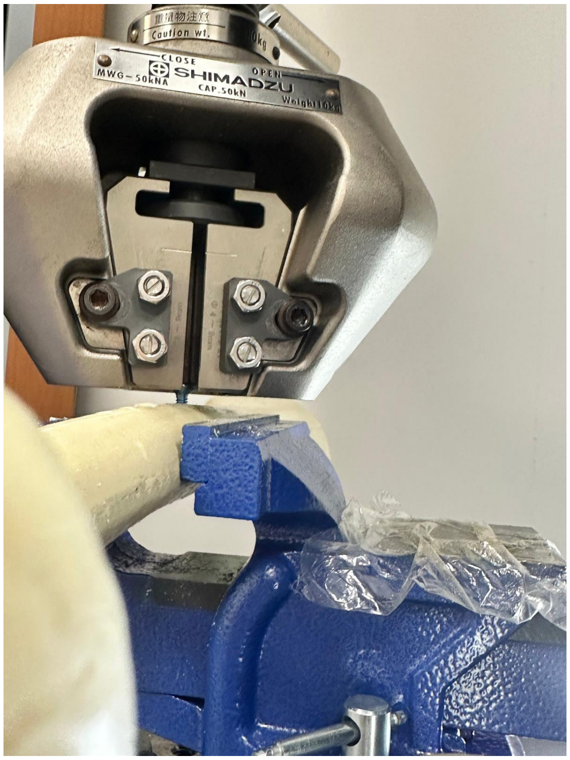

Figure 2. The installed system to test the prepared models. While the synthetic femur was affixed within the device, the head of the screw on the bone was grasped with the aid of a tool, and a tensile force was applied to the cortical screw head until pull-out (load to failure)

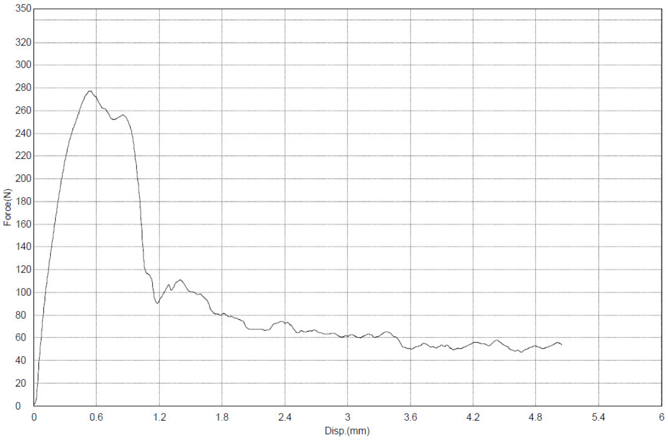

Figure 3. The force-displacement graph was constructed based on the data obtained from the experiment. In calculating the pull-out strength, the initial pull-out was defined as the moment when the resistance was first broken and the force-displacement curve first changed direction

RESULTS

It was ascertained that no synthetic bones were broken or lost during the preparation process prior to the measurement. The results demonstrated that the pull-out strength of the screws with partial contact to the far cortex ranged from 155 to 277 N, while the pull-out strength of the screws with full contact to the far cortex ranged from 178 to 256 N. In contrast, the pull-out strength in the group with at least three threads passed through the far cortex ranged from 322 to 540 N (Table 1).

A significant difference was observed in the triple comparison (p=0.021) when the pull-out strengths were compared between groups. Post-hoc analyses demonstrated that this was due to Group 3, with the pull-out strength in the group with at least three threads passed through the far cortex being significantly higher than in the other two groups (Table 2).

Table 1. Descriptive statistics of the experiment groups

Pull-out force	Group 1 (Partial contact)	Group 2 (Full contact)	Group 3 (Passed through)
Median (N)	185	235.5	401
Interquartile range	103	61	178
Minimum force (N)	155	178	322
Maximum force (N)	277	256	540

Table 2. Post-hoc analysis of the pull-out strength presenting a pairwise comparison of the groups in a cross-table format

	Group 1 (Partial contact)	Group 2 (Full contact)	Group 3 (Passed through)
Group 1 (Partial contact)	N/A	0.486	**0.029**
Group 2 (Full contact)	0.486	N/A	**0.029**
Group 3 (Passed through)	**0.029**	**0.029**	N/A

DISCUSSION

Screw systems are the most commonly utilized implants in traumatology. It is therefore imperative that healthcare professionals possess an in-depth understanding of their biomechanical properties and advantages, in order to ensure optimal fixation and prevent potential complications. It is generally accepted that cortical screws must make contact with both cortices (the near and far cortex) in order to achieve the desired compression force (1-4). On the other hand, there is a paucity of literature providing clear guidance on the extent to which the far cortex should be adhered. It is important to note that the far cortex may not always be adhered at the desired rate due to anatomical differences between patients or material supply issues. The aim of our study was to demonstrate the biomechanical superiority of partial and full contact and screw penetration of the far cortex. The most significant finding was that there was no difference in pull-out resistance between partial and full contact with the far cortex when using cortical screws. However, pull-out strength increased significantly when at least three threads were passed through the far cortex.

The value of utilizing longer screws in fracture fixation has been well documented in the scientific literature (10,11). In a study published in 2019, Fletcher et al. demonstrated that longer screws are associated with a reduced risk of cut-outs in proximal humerus fractures (11). In the case of cortical screws, the importance of screw length is further amplified, given that bicortical screw placement is crucial for achieving compression force. In contrast, the literature offers no clear explanation regarding the partial or complete adhesion of the far cortex in the context of bicortical application. From an engineering and geometrical perspective, it can be postulated that increased adherence of the far cortex will result in enhanced compression strength. Furthermore, even in instances where the far cortex is pierced, the holding and pull-out strengths will be augmented. The findings of our study provide partial support for this hypothesis. The pull-out strength was significantly increased in the group that crossed at least three threads of the far cortex, whereas no significant difference was detected between partial and complete contacts of the far cortex. This result may be interpreted as indicating that contact between the distal end of the cortical screw and the far cortex is sufficient for minimum force, but that the holding force increases after the screw threads penetrate the far cortex. However, further biomechanical and finite element studies are needed for a more comprehensive analysis of the subject.

The results of our study demonstrated that the pull-out strength of Group 3 (the group in which at least three threads of the far cortex were passed) was the highest, and that the strongest fixation was obtained with this screw application. It is also important to note that a significant limitation of biomechanical studies is the inability to consider soft tissue as a parameter. Despite the observation that the pull-out strength of Group 3 was the highest in our study, the recommendation for the routine use of this application does not align with clinical practice. It is therefore necessary to consider the balance between stability and the potential for soft tissue complications. A review of the literature reveals numerous reports emphasizing the importance of achieving a balance in this regard (12,13). In 2020, van Dijk et al. emphasized the importance of achieving an equilibrium between optimizing pull-out strength and preventing cortical penetration and soft tissue complications (14). In conclusion, the primary objective of orthopaedic surgeons is to achieve fixation strength and prevent pull-out. However, this is not the sole objective, as preventing potential irritations and soft tissue complications and preserving the patient's biological processes are also vital for fracture healing.

It should be noted that, in the course of our study, 12 reinforced third-generation composite synthetic left femur models with a resistance against up to 1533 N in mechanical tests were employed. The synthetic femur models were prepared for biomechanical testing at the actual load quality that the human bone can withstand. Conversely, it is not possible to create a synthetic bone that precisely resembles the human bone, given that the quality of human bone is influenced by a multitude of factors, including age, gender, degree of movement, and mineral density. It is therefore unfeasible to develop a synthetic model that exhibits all of the same biomechanical properties as human bone. Furthermore, synthetic models lack soft tissue support, which is a crucial component of the mechanical system in humans. Nevertheless, our comparative experiment was conducted because the synthetic bone models were prepared to withstand the actual load quality that the human bone can withstand, have similar biomechanical properties with each other and have been previously validated in the literature (15,16).

It is important to acknowledge that our study is not without limitations. The principal limitation of the study is the relatively small number of subjects. Additionally, the study's reliance on synthetic bone models, its exclusive focus on a single anatomical structure type, and the exclusion of soft tissue as a factor due to the biomechanical nature of the study may affect the generalizability of the results. Moreover, the assessment of pull-out force in the direction of screw advancement, without consideration of motion vectors, represents another limitation. Finally, the use of screws in without plates, and the absence of a fracture model in the experimental process, represent important limitations. These limitations can be addressed through comprehensive studies that incorporate finite element analysis and clinical projections on the subject.

CONCLUSION

In conclusion, screw length and far cortical adhesion are critical parameters in obtaining ideal fixation strength in traumatology. When choosing the cortical screw length, a stronger pull-out resistance can be expected with a longer cortical screw length and passing the distal end through the far cortex. However, this should be decided taking into account the characteristics of the anatomical region to be treated, the nearby neurovascular structures, and the risk of tendon-soft tissue irritation.

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REFERENCES

1. Orthopaedic Implants. https://www.orthobullets.com/basic-science/9063/orthopaedic-implants access date: 26.8.2024.
2. Roberts TT, Prummer CM, Papaliodis DN, et al. History of the orthopedic screw. Orthopedics. 2013;36:12-4.
3. Feng X, Luo Z, Li Y, et al. Fixation stability comparison of bone screws based on thread design: buttress thread, triangle thread, and square thread. BMC Musculoskelet Disord. 2022;23:820.
4. Fletcher JWA, Wenzel L, Neumann V, et al. Surgical performance when inserting non-locking screws: a systematic review. EFORT Open Rev. 2020;5:26-36.
5. Lin CC, Lin KJ, Chen WC, et al. Larger screw diameter may not guarantee greater pullout strength for headless screws - a biomechanical study. Biomed Tech (Berl). 2017;62:257-61.
6. Ricci WM, Tornetta P 3rd, Petteys T, et al. A comparison of screw insertion torque and pullout strength. J Orthop Trauma. 2010;24:374-8.

7. Chen MJ, DeBaun MR, Thio T, et al. Drilling energy correlates with screw insertion torque, screw compression, and pullout strength: a cadaver study. J Am Acad Orthop Surg. 2020;28:e1121-8.
8. Feerick EM, McGarry JP. Cortical bone failure mechanisms during screw pullout. J Biomech. 2012;45:1666-72.
9. Gustafson PA, Veenstra JM, Bearden CR, Jastifer JR. The effect of pitch variation and diameter variation on screw pullout. Foot Ankle Spec. 2019;12:258-63.
10. Baumbach SF, Synek A, Traxler H, et al. The influence of distal screw length on the primary stability of volar plate osteosynthesis--a biomechanical study. J Orthop Surg Res. 2015;10:139.
11. Fletcher JWA, Windolf M, Grünwald L, et al. The influence of screw length on predicted cut-out failures for proximal humeral fracture fixations predicted by finite element simulations. Arch Orthop Trauma Surg. 2019;139:1069-74.
12. Schmiedl A, Buchhorn A, Schönberger M. The relationship between the subclavian vessels and brachial plexus and the overlying clavicle: Anatomical study with application to plate osteosynthesis. Clin Anat. 2023;36:377-85.
13. Chuaychoosakoon C, Chirattikalwong S, Wuttimanop W, et al. The risk of iatrogenic radial nerve and/or profunda brachii artery injury in anterolateral humeral plating using a 4.5 mm narrow DCP: a cadaveric study. PLoS One. 2021;16:e0260448.
14. van Dijk PA, Breuking S, Guss D, et al. Optimizing surgery of metaphyseal-diaphyseal fractures of the fifth metatarsal: a cadaveric study on implications of intramedullary screw position, screw parameters and surrounding anatomic structures. Injury. 2020;51:2887-92.
15. Kati YA, Kose O, Acar B, et al. Risk of injury to the neurovascular structures in the pararectus approach used in acetabular fractures: a cadaver study. J Orthop Trauma. 2021;35:e13-7.
16. Gümüştaş SA, Tosun HB, Ağır İ, et al. Influence of number and orientation of screws on stability in the internal fixation of unstable femoral neck fractures. Acta Orthop Traumatol Turc. 2014;48:673-8.