Stress on Bone from Placement and Removal of Orthodontic Miniscrews at Different Angulations

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The present study was conducted to measure the stress on bone from insertion and removal of TADs at two common sites using different angulations of insertion. The force required for mechanical failure was also assessed.

Materials and Methods

Two rosette-type stress-strain gauges, each with three leads connected to a strain-measuring device,* were attached with adhesive** to the dried bone of a dissected human adult fixed cadaver skull at two locations: adjacent to the midpalatal suture, and at the alveolus adjacent to the maxillary left first premolar and canine. Four TADs*** (1.8mm in diameter, 8mm long) were inserted manually by a single operator with a contra-angle driver to avoid interference with the soft tissue. Two TADs were inserted to their full 8mm length adjacent to each gauge, one perpendicular to the bone and one at an angle of 45°, measured using a conventional protractor. The forces exerted on the bone were measured in units of microstrain, which were converted to units of force (Newtons per square millimeter). To test for mechanical failure, an .012" stainless steel ligature was attached to the head of each TAD, and progressive forces were exerted up to 15lbs. For the TADs that were placed at 45° angles, the load was applied at an angle of 135°. Finally, the stress on bone was measured upon removal of each TAD.

*Model P3 Strain Indicator, Vishay Intertechnology, Inc., Malvern, PA; www.vishay.com.

**M-Bond, Vishay Intertechnology, Inc.

***IMTEC, trademark of 3M Unitek, 2724 S. Peck Road, Monrovia, CA 91016; www.3Munitek.com.

Results

On insertion, the maximum plain stress on bone was greater for the TAD angled at 45° than for the one at 90° (75.1N/mm^2 vs. 15.2N/mm^2 in the palate; 33.8N/mm^2 vs. 9.7N/mm^2 in the alveolus). On removal, the maximum plain stress on bone was also greater for the TAD angled at 45° than for the one at 90° (43.4N/mm^2 vs. 5.5N/mm^2 in the palate; 11.72N/mm^2 vs. 2.1N/mm^2 in the alveolus).

Data were analyzed using a three-way analysis of variance. The differences in force between the two insertion angles were found to be statistically significant ($F = 12.287$; $df = 1, 4$; $p = .025$). Force differences between the two insertion sites ($F = 4.762$; $df = 1, 4$; $p = .094$) and between insertion and removal ($F = 3.589$; $df = 1, 4$; $p = .131$) approached, but did not reach, the conventional significance level of $p < .05$.

None of the TADs showed any signs of mechanical failure when as much as 15lbs of load was exerted.

Discussion

To avoid root injury, some clinicians have advised inserting TADs at an angle of 30-45° in the maxilla and 10-20% in the mandible, instead of perpendicular to the bone.[1-3] Although various authors have reported high failure rates associated with miniscrew implants,[4-11] the relationship between miniscrew angulation and stress on bone has not been previously discussed in the literature. Theoretically, a more acute entry angle should result in increased stress because of the greater

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amount of cortical bone that the TAD has to penetrate[12] (Fig. 1). Our finding of significantly more stress on bone with TAD insertion at 45° than at 90° supports this hypothesis.

Increased stress may draw more cytokines, macrophages, and inflammatory mediators to the site, possibly resulting in a higher risk of TAD failure through loss of primary stability. Most dental implant failures have been attributed to biomechanical stresses and strains at the bone-implant interface, resulting in peri-implant inflammation that can lead to bone loss.[13-17] The absence of mechanical failure in our study from loads as high as 15lbs further substantiates this theory. Soft-tissue inflammation also contributes to TAD failure: TADs placed in nonkeratinized or thick keratinized gingiva are more likely to fail.[5,18,19]

Insertion torque is another potential factor in TAD failure. Lim and colleagues reported that increased torque can cause degeneration of bone at the implant-tissue interface.[20] Moreover, increased torsional stress during placement can result in TAD bending and thus lead to TAD fracture and small cracks in the peri-implant bone, further compromising implant stability.[21-24] The insertion torque increases with cortical bone thickness,[25] which increases with the acuteness of the entry angle.

We also found that removal of a TAD that had been inserted at an angle exerted greater stress on bone than when the miniscrew was placed perpendicular to the bone. The result may be a higher risk of TAD fracture on removal and of patient discomfort from bone microfractures.

Conclusion

Increased insertion torque combined with the increased stress on bone resulting from placement of a TAD at an angle may raise the risk of inflammation and thus of TAD failure. Therefore, we believe that as long as root damage can be avoided, TADs should be placed as perpendicular to the bone as possible.

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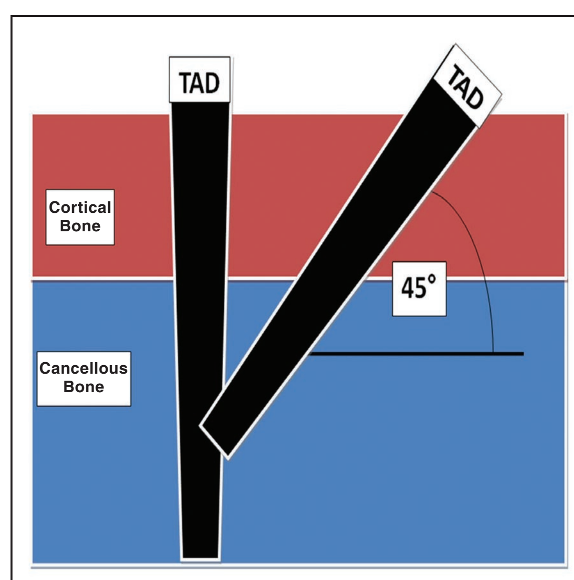

Fig. 1 Temporary anchorage device (TAD) passes through more cortical bone when inserted at 45° than at 90°.

ACKNOWLEDGMENTS: The authors acknowledge the University of Manitoba Faculty of Dentistry Endowment Fund for providing financial assistance for this study. We also thank Bill Pylapass, Dr. Thomas Klonisch, and Larry Mullins.

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