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Retention of mini-screws in orthodontics: a comparative in vitro study on the variables

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ABSTRACT

Objectives: The study aimed to correlate the different lengths, angles of insertion and the mini-implant material and determine the most retentive combination.

Materials and methods: 48 mini-implants (24 Titanium and 24 stainless steel) of lengths 6mm, 8mm and 1.5 mm diameter were inserted into the humerus bone of goat at two different angulations, 600 and 900. To insert the mini-implant in the respective angulations, a custom made template was made and the angles were confirmed with digital radiographs. Force was applied to the mini-implants with a universal testing machine, and the compressive load to failure was measured.

Results: Results revealed that the implant's stability was positively correlating with the length of the implant. A perpendicular angulation produced more stability. Moreover, titanium mini-implants had more resistance to compressive load than stainless steel mini-implants. The results are based on an in-vitro study conducted on the humerus bone of the goat and hence these factors are not the only ones governing the stability of mini-implants in-vivo.

Conclusion: The mini-implants length, its angulation in the bone, and mini-implant material were factors affecting its stability. In this study, titanium mini-implant of 8mm length angulated at 900 was stable than their counterparts. We studied the factors that affect mini-implants' stability through in-vitro studies, which may vary when placed in-vivo. The same environment cannot be simulated for in-vitro studies.

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INTRODUCTION

Every action has an equal and opposite reaction. Newton's third law applies to every matter in the universe. Similarly, in orthodontics, when retraction is done with the molars as an anchorage, an equal force is felt on the molars, which is undesirable. Anchorage hence is an essential aspect of orthodontics. Although the anchorage principle had been understood since the 17th century, clear articulation was not done until 1923. Louis Ottofy defined it as "the base against which orthodontic force or reaction of orthodontic force is applied." [1] Absolute anchorage has been a long sought after, but rarely achieved, treatment ideal.[2] There have been many attempts to devise suitable anchorage methods, including conventional intraoral and extraoral appliances. However, all intraoral appliances show some loss of anchorage. Extraoral appliances, on the other hand, do not provide reliable anchorage without patient compliance.[3] Ideal anchorage should fit into two criteria:

a) Absolute resistance to unwanted tooth movement, and

b) Independence from patient compliance.[4]

Implants are currently used in dentistry and orthopedics for various applications. The biologic basis for osseointegration was provided by the pioneering work of Branemark.[5] Since then, to overcome the problems associated with anchorage loss, skeletal anchorage methods have been developed and are being increasingly used.[6] When using skeletal anchorage such as osseous dental implants,

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miniplates, mini-screws, or micro-screws, clinicians can expect reliable anchorage without patient compliance.[3] Among the anchorage, as mentioned earlier, mini-screw implants have been increasingly used because of their absolute anchorage, easy placement and removal, and low cost. The mini-screw implants' small size allows them to be placed into bone between the teeth, without osseointegration, thus expanding their clinical applications.[3] However, the risk and utility of Temporary anchorage devices (TAD) are questions that need to be answered.

Mini-screws do loosen during the treatment and do not achieve the high success rates associated with them. The primary stability of orthodontic mini-screws can be attributed to their mechanical retention. Primary stability is determined by bone properties, surgical techniques, and implant size and design.[7] Quantity (bone volume) and quality (bone density) of alveolar bone are important factors for implants' stability. Anatomical characteristics such as cortical bone might differ between the jaws. By angulating the mini-screws, the thickness of cortical bone contact with the mini-screw might increase.[8] Implant diameter, length and presence of inflammation have also been reported as factors affecting the success of TADs.[4] There were no differences in histologic responses between Stainless Steel and Titanium alloy MSIs with or without loading. Thus, the material of the implant was also taken into account for comparison.

Therefore, our study aimed to test the effect of mini-implant material, mini-implant length, design, and insertion angle on its primary stability.

MATERIALS AND METHODS

The ethical committee approved the study (SDC/IHEC/2017/MDS/16). Mini-implants of lengths 6mm and 8mm and 1.5 mm diameter were selected for the study as they have been most commonly used. The sample size included 48 mini-implants of 1.5 mm diameter (SK Surgicals), of which 24 were of Titanium (Ti) and 24 of Stainless-steel (SS). The Titanium alloy is used instead of pure Titanium because of its superior strength, which allows it to overcome common problems with pure titanium mini-implants such as fractures or distortions. Stainless steel is one of the most frequently used oral surgical and orthopedic implant materials because of a favorable combination of mechanical properties, biocompatibility, cost-effectiveness, and manufacturing ease. Out of the 24 mini-implants, 12 were of 6 mm in length and the remaining 8mm in length both for Stainless steel and Titanium. Two insertion angles were investigated by inserting the mini-implants at an angle of 60±10 and 90±10 with the help of a custom-made template (Figure 1) into the humerus bone of the goat. To establish the correct angulation while inserting the mini-implant, a customized template was fabricated (Figure 1).

Figure 1. *Custom made template*

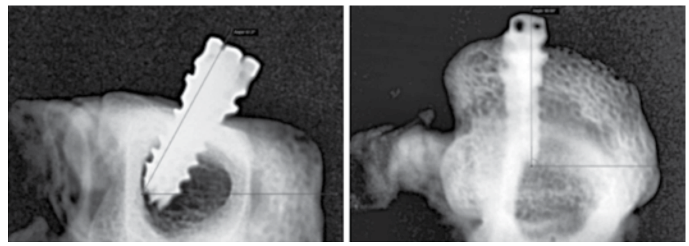

Figure 2. *Radiograph showing the angulation of the miniscrews*

Two 19-gauge Stainless steel wires were straightened and soldered at an angle of 60±10. A transparent plastic tube of length 20mm and diameter 6mm was cut with a micromotor and a disc-bur, approximately 1/3rd of the mini-implant driver's length, and was attached to the 19-gauge wire fabricated with the help of self-cure acrylic.

Similarly, a customized template of 90±10 angulation was fabricated. The bone was stabilized with the help of a vise grip and implants were screwed to the bone at angles 600 and 900 with the template held in its position and stabilized by sticky-wax. Confirmation of angulation was done with a digital radiograph and measuring in the software (Figure 2). Following this, a force was applied to the bone with a Universal testing machine (INSTRON) and the force at breakage was measured (Figure 3).

Figure 3. *Universal Testing machine (Instron model 8800 MK3305 – Servo-Hydraulic)*

Force to fail was analyzed using unpaired t-tests for two-group comparisons and Analysis of variance (ANOVA) for three or more comparison groups (Chart 1). Post-hoc analyses used the Tukey-Kramer method. P-value of less than 0.05 was considered significant.

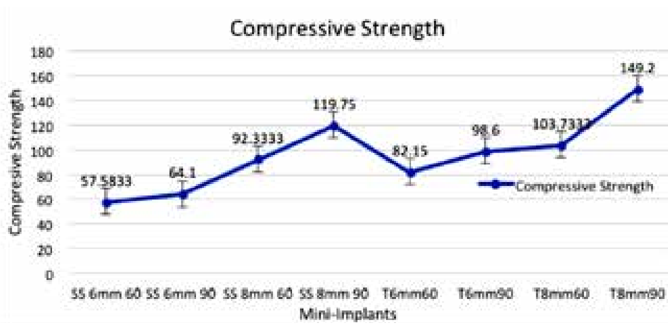

Chart 1. Descriptive Statistics for Stainless Steel and Titanium mini-implants of length 6 mm and 8 mm with varying angulation of 600 and 900 calculated through Analysis of Variance

RESULTS

The initial force to fail tests was recorded on 48 implants. The results are based on an in-vitro study conducted on the humerus bone of the goat and hence these factors are not the only ones governing the stability of mini-implants in-vivo. Nevertheless, the following factors also play a significant role in determining the stability of the mini-implants intraorally.

Implant material

Keeping the other variables constant, when Stainless-Steel mini-implant was compared with titanium mini-implant, differences were significant with titanium mini-implant showing greater stability than its stainless-steel counterpart.

Implant length

When the angulation was kept a constant, stainless-steel mini implant showed a significant difference in change in length. SS mini-implants, when angulated at 600 and 900 had a p-value of 0.000 on changing the length from 6mm to 8 mm, with 8 mm mini-implants showing superior strength.

However, when titanium mini-implants were used, a significant difference (p=0.01) was found only at an angulation of 900 when the length was changed with an increased length showing higher stability. An insignificant difference at changing lengths was found at 600 angulations (p=0.231).

Implant angulations

Keeping the length constant, when angulations were changed, stainless steel mini implants the difference was significant at 8mm length with 900 angulation showing greater stability than 600 (p=0.001). However, at 6mm length, the difference was insignificant (p=0.665).

The results of titanium mini-implants for different angulations were similar to their stainless-steel counterparts, with a significant difference seen at changing angles from 600 to 900 at 8mm length (p=0.001).

DISCUSSION

This study's results have favored the previous reports and have even a difference of opinion in with some of the studies. Petrey JS et al4 reported a success rate of 80.5% to 95.2% for TAD's. In this study, the variables that were compared included the implant's material, length of mini-implant, and the angulation of the implant with which it was inserted into the humerus bone of the goat, keeping the diameter of the mini-implant as a constant factor (1.5 mm).

In orthodontics, stainless-steel and Titanium alloys are being used as TAD's.[9] Though the mini-implants' material of choice has been titanium alloy, the high cost associated with it can be a limiting factor.[9]

On comparison between the two materials – Stainless steel and Titanium alloy, results revealed that Titanium alloy mini-implants had a higher compressive load indicating their superior properties compared to Stainless steel. The results of this study were consistent with the study done by Ashith MV et al[10]. They stated that on the comparison, stainless-steel mini-implants had a higher failure rate (50%) when compared to titanium mini-implants (10%). They accounted that the probable reason for the increased failure rate was the less biocompatibility of the stainless-steel mini implants that caused peri-implantitis, thereby causing mobility of the mini-implant[10]. However, reports that are against this result was also found. Bollero P et al[11] and Brown RN et al[12] measured the removal torque of the two different implant materials and stated that the results were statistically insignificant and hence stainless-steel mini-implants can be used for anchorage purpose in orthodontics. Bollero P et al[11] also did a scanning electron microscope (SEM) analysis of the implants after they were removed from the bone. Both the Stainless-steel and Titanium mini-implants showed no signs of osseointegration. Pan CY et al[9] used the resonance frequency of the mini-implant screwed in the artificial bone as the variable for testing the primary stability and found no statistically significant difference between the two materials.

On comparison between the different angulations (600 and 900) and keeping the other variables (material and length of mini-implant) constant, the present study showed that mini-implant of length 8 mm irrespective of the material showed a significant difference in the compressive strength at varying angles with perpendicular angulation showing more resistance to force. This indicated that a 900 angulated mini-implant was more stable than 600. The results of this study were consistent with the works done by Petrey JS et al., Omar A et al., Lee J et al.[4,13,14] They stated that vertical placement of the mini-implant in the cortical bone provides the most resistance. Omar A et al[13] and Lee J et al[14] stated that when the mini-implant is placed at an angle of 900 to the cortical bone, the von Mises stresses and displacement of the mini-implant were the least. In this study, the 6 mm mini-implant showed statistically insignificant value. This can be attributed to the cantilever load arm because 6 mm length invariably produced a small lever arm and oblique insertion (600) moreover produced a more cortical bone contact area. Contrary to this study were the results of the study done by Wilmes B et al., Maya RR et al. where they stated that mini-implants inserted at an angle of 900 displayed a greater insertion torque than the ones inserted at an angle of 600 and hence were less stable. [15,16]

Keeping the other variables (material and angulation) constant, when the effect of length of mini-implants on its primary stability was compared, the results showed that on increasing the length of mini-implants, the stability of mini-implants increased for both the angulations. Congruent with this study was the work done by Petrey JS et al. Kim YK et al., Mohammed HI et al., Chatzigianni A et al.[4,17,18,19] Kim YK et al[17] stated that long mini-implant provides higher stability with higher torque during removal. However, the long mini-implant can fracture during insertion because it needed a higher insertion torque[11]. Contrary to the present study were the results of Singh AK et al[20] and Ohali HA[21]. They stated that an increase in length did not affect the stability of mini-implant.

CONCLUSION

The length of the mini-implants has a direct effect on primary stability. More the length of the mini-implant, there will be increased insertion depth and thereby an increase in primary stability.

Placement at 900 to the bone is the most retentive insertion angle.

Titanium mini-implants are more stable when compared to their stainless-steel counterparts.

Of the types of mini-implants used and variables tested in this study, the results indicated that a Titanium mini-implant of 8mm length inserted perpendicular to the bone gives maximum retention.

Limitation of the study

We studied the factors that affect mini-implants' stability through in-vitro studies, which may vary when the mini-implants are placed in-vivo as the exact environment cannot be simulated for in-vitro studies. We have considered only the implant-related factors. Some non-significant results might be due to the low sample size taken.

CONFLICT OF INTEREST

The authors of the present article declare no conflicts of interest.

Table 1. *Descriptive statistics indicating maximum and minimum compressive load (N - Newton)*

Descriptive Statistics for SS and Titanium mini- implants					
Implant material, Length & Angulation	Number	Minimum compressive load (N)	Maximum compressive load (N)	Mean (N)	Std. Deviation
SS 8 mm 60º	6	86.10	97.30	92.3333	4.54738
SS 8 mm 90º	6	103.30	132.80	119.7500	11.01558
SS 6 mm 60º	6	39.60	77.10	57.5833	14.70448
SS 6 mm 90º	6	59.30	73.80	64.1000	5.35388
T 8 mm 60º	6	66.70	142.50	103.7333	25.60615
T 8 mm 90º	6	130.50	174.60	149.2000	16.36594
T 6 mm 60º	6	64.80	100.80	82.1500	14.53984
T 6 mm 90º	6	74.10	124.60	98.6000	17.35915

Table 2. *Significance (p value) of mean difference of Post HOC Tukey HSD test for Multiple comparisons based on comparing the peak load force to failure in stainless steel mini-implants at varying lengths (6mm and 8mm) and varying angles of insertion (60º and 90º) *p=0.05.*

(I) Group	(J) comparison group	Mean Difference (I-J)	Std. Error	P value
SS 6 mm 60º	SS 6 mm 90	-6.5167	5.67823	.665
	SS 8 mm 60	-34.7500*	5.67823	.000
	SS 8 mm 90	-62.1667*	5.67823	.000
SS 8 mm 60º	SS 6 mm 60	34.7500*	5.67823	.000
	SS 6 mm 90	28.2333*	5.67823	.000
	SS 8 mm 90	-27.4167*	5.67823	.001

Table 3. *Significance (p value) of mean difference of Post HOC Tukey HSD test for Multiple comparisons based on comparing the peak load force to failure in Titanium mini-implants of varying lengths (6mm and 8mm) and varying angles of insertion (60º and 90º) *p=0.05.*

(I) group Titanium	(J) group titanium	Mean Difference (I-J)	Std. Error	P value
T 6 mm 60º	T 6 mm 90	-16.4500	10.94024	.454
	T 8 mm 60	-21.5833	10.94024	.231
	T 8 mm 90	-67.0500*	10.94024	.000
T 8 mm 60º	T 6 mm 60	21.5833	10.94024	.231
	T 6 mm 90	5.1333	10.94024	.965
	T 8 mm 90	-45.4667*	10.94024	.003

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