Assessment of primary stability of mini-screws with variation in thread shape

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Introduction: an in vitro evaluation of thread outline variation of orthodontic mini-implant for axial pullout test on the strength of the orthodontic mini-screws.

Materials and Method: This study was done on 35 Titanium mini-screws. The mini-screws were divided into five test groups. Each group consisted of 7 mini-screws. The mini-screws in Group A containing buttress reverse thread shape, acted as a control group for their respective experimental group containing other thread shaped mini-screws. The 35 blocks were made with synthetic bone support Rigid Polyurethane foam. Then the mini-implants were inserted at these point with implant driver perpendicular to the surface of sample block. The load was smeared to the head of mini-implant at the speed of 10 mm/min of cross head. The highest load at which the mini-implant dislodge was recorded in the universal testing machine.

Results: The results of comparison shows that Group A shows highest pullout resistance value (212.787 N) then group D (204.43N), Group E (195.681N), Group C (182.234N) and group B (174.160N). The above pullout resistance value are in decreasing order. Reverse buttress thread shape had highest resistance to pullout force in axial direction and buttress thread shape had least resistance to pullout force test. While comparing the groups with control group, it was found that comparison between group A and B, and comparison between group A and C shows the statistically significant values as p value < 0.05 , that is 0.003 and 0.002 respectively.

Conclusion: The Buttress Reverse thread design may be more useful as it shows highest pullout resistance value than other thread shape form i.e. Rounded thread shape, Trapezoidal thread shape, 75 degree joint profile thread shape and Buttress thread shape in decreasing order respectively.

Key Words: Mini-screws, thread shape, axial pull-out test

P.I Branemark, in 1960s, found that bone had a great attraction for the titanium and devised the term osseointegration [1]. This phenomenon completely changed the outlook of the anchorage plan in the orthodontics. The first key factor to success in treatment is a sufficient primary stability [2,3]. The accomplishment of the skeletal anchorage system using mini-implant is always associated to their constancy in bone. Most of the failures occur immediately after mini-implant placement because the absence of primary stability may lead to gradual mobility of the device and to its succeeding loss [4]. The features that impact the instant stability are correlated to the quantity and quality of bone, the design of the device, and the insertion technique.

The thread design primarily, the form of the thread shape, influences bone/implant contact, the stress load on the bone and insertion torque. Self tapping screw has blunt tip, to prevent inadvertently root penetration, and round flanks, as these flank does not have to displace much of the bone and cut through the wall of hole [5]. As little osseous tissue is compressed or displaced there is less pressure necrosis and hence little discomfort to the patient. While the self drilling screws have the sharp tip and flank to bore and cut through the bone. The volume of the bone displaced is high hence there is lot of tension is created in the bone.

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Also pressure necrosis may result, making patient feel more discomfort. Some recent self drilling implants are available in dual thread type with trapezoidal thread in cervical area to increase the cortical bone support and reverse buttress in the apical area with cork screw like tip helps in easy insertion of screw into bone [5].

The mechanical evaluation of the retention property of a material or a device when it is entrenched in something is done with the help of pullout test strength. The pullout force is principally done to express the shear strength of mini-implant embedded in bone specimens [3]. Nienkempera et al used pullout load to define the stability of mini-implant with different cortical thicknesses at dissimilar healing times [2].

The aim of the present in-vitro study was to examine how thread shape of temporary anchorage device and pullout force are associated in recitation primary stability.

OBJECTIVE:

To assess the role of differences in thread shape of orthodontic mini-implant on axial pullout strength of orthodontic mini-screws

MATERIALS AND METHOD

The concerned ethical committee of University and College approved objective of present study along with the materials and methods.

MATERIALS

1) 35 Titanium Mini-Screws 7 of each group (S.K. SURGICALS, PUNE) (Fig.1 A-E)

The screw shapes used are
Buttress reverse thread shape (control) (Figure 1 A)
Buttress thread (Figure 1 B)
75^{0} joint profile thread (Figure 1 C)
Rounded thread (Figure 1 D)
Trapezoidal thread (Figure 1 E)

2) Rigid synthetic polyurethane foam (Axson; Cergy, France) (Figure.2)
3) Round bur and drill bur (Figure.3)
4) Insertion driver (Figure.3)
5) Universal testing machine (model no. 33R 4467, Instron 182 Ltd., Buckinghamshire, England) (Figure.4)

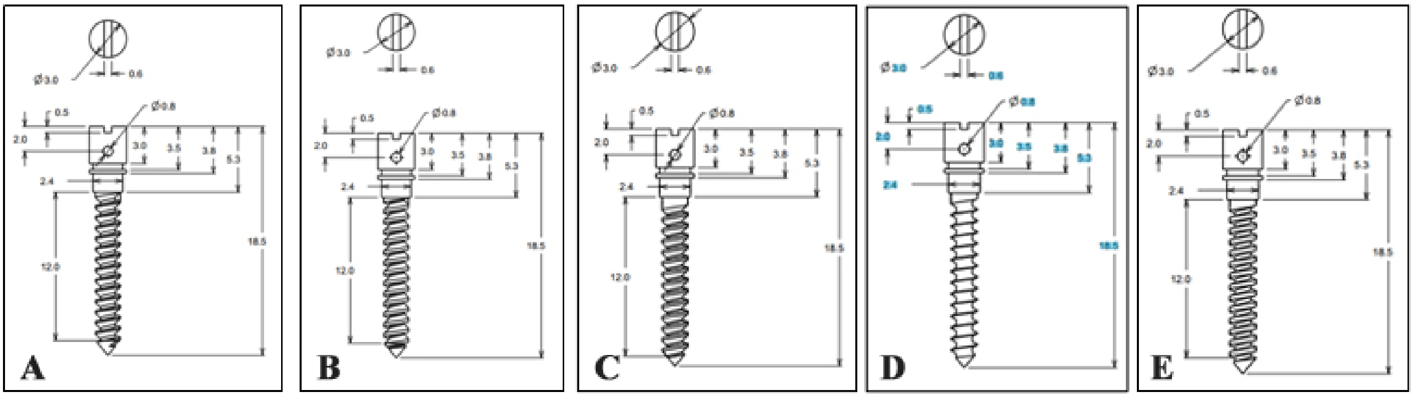

Fig 1 A Buttress reverse thread shape (control), B: Buttress thread, C: 75^0 joint profile thread, D: Rounded thread, E: Trapezoidal thread

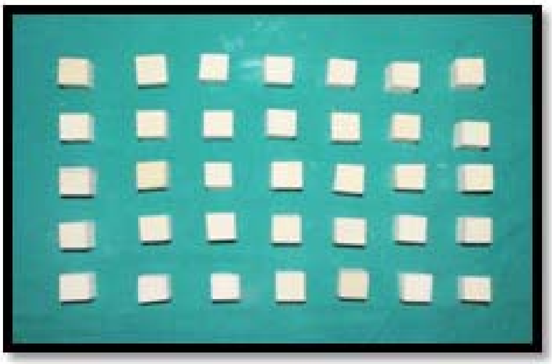

Fig. 2 Rigid synthetic polyurethane foam

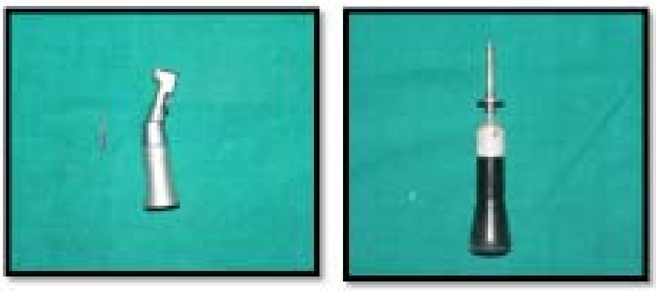

Fig. 3- Round bur and Drill bur and Insertion driver

Fig 4. Universal Testing Machine

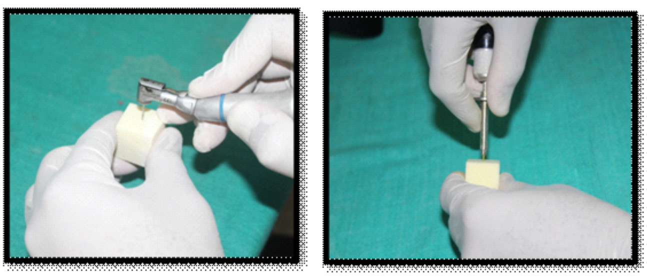

Fig 5. Initial drill and Placement of mini-implant

METHOD:

Total 35 mini-implants of five different experimental designs with altering the thread shape and keeping all other characteristics constant were manufactured. In the present study, mini-implant used were taking a length of 12 mm and a diameter of 2 mm, the lengthiest mini-implant were used because the no of thread that incorporated into block were more. The five designs were divided into 5 groups each having 7 samples.

The groups were -
The screw shapes thread used are
Group A : Buttress reverse (control)
Group B : Buttress
Group C : 75^0 joint profile
Group D : Rounded
Group E : Trapezoidal

In the present study, a synthetic homogeneous material was used; which permitted us to reinvent under in-vitro conditions the worst clinical conditions. Rigid Polyurethane foam (Axson; Cergy, France) was used as a synthetic bone support in pull out strength evaluations. The blocks of size 2 × 2 cm were made from polyurethane foam (Fig.2). The blocks having uniformity, equal surface consistency, homogeneity and uniform density were included while the blocks having porosity and surface cracks were excluded from selected samples.

So, total 35 blocks were made. On upper surface of an each block sample, geometric center was marked. After that the hole was made at the center with the round bur and drilling (1.5 mm diameter) was done to the corresponding depth. Then the mini-implants were inserted at these point with implant driver perpendicular to the surface of sample block (Fig.5).

Then for the pullout test, the blocks were housed in the vice of the universal testing machine (Fig.4). The head of the mini-implant was held in chuck attached to load cell of universal testing machine (capacity of 1000 N Max) (Fig. 6). The load at cross head speed of 10 mm/min was applied to the head of mini-implant. The maximum load at which the mini-implant dislodge was recorded in the universal testing machine software.

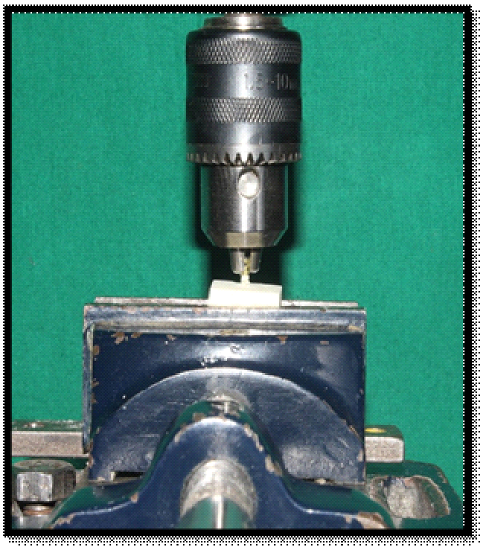

Fig. 6- Axial pull out test along long axis of Mini-implant

STATISTICAL ANALYSIS

The statistical analysis was performed using SPSS software (SPSS version 16, IBM, USA). Data assessment was done by applying specific statistical tests to evaluate the statistical significance of the results. The normalcy of the data was checked by the Kolmogorov- Smirnov test and the data was found to be not normal, hence, parametric tests were used for analysis. Evocative statistical values were obtained at pull out load of all the study groups. To rule out the statistical significance, the non-parametric test was performed. When difference was noted, further the Mann-Whitney U test was executed to recognize which groups have value at $P < 0.05$.

RESULTS

Descriptive statistical values of pull out load of all the study groups were obtained. **Table I** shows the standard deviations and means for each thread design of mini-implant. The non-parametric analysis was done to determine significance. **Table II** shows Comparison of Pull out Load (N) amongst the various study groups using Kruskal-Wallis Test. **Group A** shows highest pull out resistance than other groups, then **Group D, E, C, B** in decreasing order respectively.Mann-Whitney U test was executed to recognize which groups have value at $P < 0.05$. Significant difference was seen between the buttress reverse screw Group A (212.787 N) and that of the buttress thread profile Group B (174.160 N) **Table III.**

Comparison of Pull out Load (N) amongst the various study groups was done using Kruskal-Wallis Test. The results of comparison shows that Group A shows highest pullout resistance value (212.787 N) then group D (204.43N), Group E (195.681N), Group C (182.234N) and group B (174.160N). The above pullout resistance value are in decreasing order. Group B (174.160N) showed least pullout resistance value among all groups in this study. This concluded that the thread shape plays an important role in axial pullout test of mini-implant. Reverse buttress thread shape had highest resistance to pullout force in axial direction than other thread shapes that were used in this study and buttress thread shape had least resistance to pullout force test.

The pairwise comparison with Mann-Whitney U test was done between control group and other groups. While comparing the groups with control group, it was found that comparison between group A and B, and comparison between group A and C shows statistically significant variance as p value < 0.05 , that is 0.003 and 0.002 respectively. Comparison between group A and D, and comparison between group A and E demonstrations no statistically significant variance as p value >0.05, that is 0.085 and 0.0142 respectively.

The Comparison between group B and C stated no any statistically significant difference and comparison between group B and D and comparison between group B and E had statistically significant difference as p value >0.05. Also the association between group C and D , association between group C and E and association between group D and E indicates no statistically significant variance as p value >0.05.

This stated that, statistically significant variance present between the group A and group B with the group A providing more pullout resistance than the group B; the group C, group D, and group E thread designs undesirably affected the pullout resistance values.

Table I: Pull Out Load (N) amongst the various study groups

	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	max
					Lower Bound	Upper Bound		
GroupA	7	212.787	12.965	4.900	200.796	224.778	194.72	231.22
GroupB	7	174.160	10.488	3.964	164.461	183.860	165.90	195.51
GroupC	7	182.234	9.182	3.470	173.743	190.726	169.34	190.55
GroupD	7	204.433	38.311	14.480	169.001	239.865	177.90	288.31
GroupE	7	195.681	18.568	7.018	178.509	212.854	166.99	223.31

Table II: Comparison of Pull Out Load (N) amongst the various study groups using Kruskal-Wallis Test

TEST	
Chi-Square	16.569
df	4
Asymp. Sig. (p value)	0.002 (HS)

Table III: Pairwise comparison of the study groups using Mann Whitney U test

Study group		Mann Whitney U test (z value)	Sig. (p-value)
Group A	Group B	-3.003	**0.003**
	Group C	-3.130	**0.002**
	Group D	-1.725	0.085
	Group E	-1.469	0.142
Group B	Group C	-1.469	0.142
	Group D	-2.364	**0.018**
	Group E	-2.108	**0.035**
Group C	Group D	-1.469	0.142
	Group E	-1.597	0.110
Group D	Group E	-0.064	0.949

DISCUSSION

The primary stability of mini-implant is crucial in clinical use as of early loading or immediate loading in many clinical situation [6]. The host factor and the screw factor are the two parameters that mark the initial stability of a screw. The host factor is associated to the quality and quantity of the bone where the screw is inserted. The screw factor is related to the parameter of the screw diameter, design, shape and length of the thread. Numerous screw designs have been introduced to increase prime stability. In prosthodontic, it was conveyed that a tapered design can augment firmness for immediate loading by cumulative the mechanical contact between the surrounding bone and the dental implant[7].

Numerous thread designs have been manufactured for the clinical use. The original Branemark screw had a V-shaped thread design as a means of placement into a threaded osteotomy[1]. Steigenga et al stated that the reverse buttress thread shape is amend for pull-out loads[8]. The reverse buttress thread designed such that it has less number of threads and less thread depth. Buttress threads have often been used in the construction of artillery, particularly with the screw- type breech block. They are also often used in vises, because great force is only required in one direction [1,9,10] . The buttress reverse thread form is the reverse thread form of buttress thread shape[1,10]. 75^0 joint profile thread shape is the shape of the thread in which the flank angle is 75^0. In rounded thread design form, the large space present between the rounded crests and roots which made this form resilient to debris and thread damage[1,9,10]. The rounded edges decrease the stress on softer structures at a point of insertion. Trapezoidal thread forms trapezoidal outlines at thread profile design. Trapezoidal thread are the most commonly used design for lead-screws (power screws). Trapezoidal thread offer simplicity of manufacture and high strength. Trapezoidal thread is stronger than a comparably sized square thread design; and it makes for smoother assignation of the half nuts on a lathe lead-screw than square thread design does.

Currently standardize material Rigid polyurethane foam is recommended for analyzing orthopedic devices and instruments. [12]. The purpose of using PU foam blocks is in-vitro studies for quantitatively determining some functional factors of orthopedic implants such as pull out stiffness, stability and strength. Miyashiro [11] found that PU foam bone substitutes used for biomedical studies on implant supported prosthesis tension test, thus concluded that polyurethane foam can be used in mechanical analysis of human bones studies. The polyurethane has found an important and unique position in orthopedic biomechanical implant studies due to its similar properties with cancellous bone in terms of its material properties and resemblance. The PU-foam was used mainly in biomedical experimental studies, as they help to achieve the optimum values in various surgical procedures and to evaluate the stability of implant. The PU-foam based synthetic bones are capable of producing reproducible results as they have consistency and uniformity in their microstructural properties that are so difficult to achieve with human cadaver bones[12].

In present study, the pullout tests were completed by application of vertical forces, parallel to the long axis of the mini-screws. A pullout strength test is another ancillary test for evaluating the anchorage potential of the mini-screws. The test is performed such that measures the essential tensional force directed vertically to bone into which an implant is inserted in bone. Pullout tests have been extensively used for the evaluation of properties of implants in orthodontics and prosthodontics.

Sakin and Salmoria stated that to assess the design of implants and the mechanical interface between bone and implants, Pullout strength could be used[13]. In orthodontics, pullout strength test is mostly used to designate the shear tension of mini-implant placed in bone or similar material. Nienkemper et al carried out pullout load test to evaluate the steadiness of mini-implant with variation in cortical thicknesses at different healing times[2]. Migliorati et al used pullout load test to verify the effect of mini-screw implant positioning on the resistance to the failure[3].

Salmoria et al concluded that pullout load test measurements were significantly more in the posterior part than the anterior of the mandible of dog specimens[14]. They also found a weak association between pullout and cortical bone thickness hence pullout load test declines over time, which they associated to the resorption of the cortical plate. Salmoria et al[14] concluded that mini-screw pullout tests also been done to appraise different designs. Carano et al[15] who studied three different designs of mini-screws with same dimensions, they found that screws with asymmetric cut design show more pullout values.

The result of the present study concluded that there was significant difference in the variations in thread designs of the mini-screws, thereby confirming that shape and design of the thread marks the mini-screw's primary steadiness[16]. There was substantial decrease in pullout load test was found in buttress reverse thread design, Rounded thread shape, Trapezoidal thread shape, 75^0 joint profile thread shape and Buttress thread shape in decreasing order respectively. This finding was similar with previous clinical and non-clinical studies, presenting a better pullout load test presentation of mini-implant characterized by an asymmetrical thread shape[15-18]. The geometry of the thread that was tending toward the tip, because of which it showed less resistance to removal in an axial direction. In present study, it can be concluded that, as the 75^0 joint profile thread showed the second highest pullout load test in terms of mean differences from the control design, it can be predicted that the extent of the angles of the thread might have influence on the mechanical steadiness of mini-implant.

The present study was carried out using synthetic bone support Rigid Polyurethane foam, which does not stimulate the intra-oral environment and small sample size were the limitations of the study. In the present study, the pull-out test was performed in which the vertical forces were directed parallel to the long axis of the screw. But during active orthodontic treatment, the mini-screws subjected not only to vertical forces but also the horizontal and torsional forces[19]. Hence further studies are required to evaluate the pull-out test with different force pattern and finite element analysis to evaluate the stresses around mini-screws to the pull-out test.

CONCLUSION:

·The result of the present study concluded that the statistically significant variance was noted between the groups with reverse buttress design thread shape had highest resistance to pullout force in axial direction and buttress thread shape had least resistance to pullout force test.

·The Buttress Reverse thread shape design may be more attractive for use because, it shows highest pullout resistance value than other thread shape form i.e. Rounded thread shape, Trapezoidal thread shape, 75^0 joint profile thread shape and Buttress thread shape in decreasing order respectively.

Acknowledgement: We thank Mr Vikas Ranjan Kawane, Sr Design and Development Engineer at ZF Steering Gear India Ltd, for mini-screw shape and design.

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