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To evaluate and compare the primary stability of self-drilling orthodontic titanium mini-implants (Modern Orthodontics) inserted at various angles into polyurethane bone blocks using a pull-out test- An In-Vitro Study

Dr. Abdulrehman Irfan Foujdar[*1], Dr. Chaitali Purushottam Rekhate[2], Dr. Sameer Patil[3], Dr. Sheetal Potnis[4], Dr. Arun Mhaske[5], Dr. Sandeep Jethe[6]

[*1]Assistant Professor,Department of Orthodontics & Dentofacial Orthopedics,D.Y. Patil Dental School, Pune

[2]Assistant Professor,Department of Orthodontics & Dentofacial Orthopedics ,Nanded Rural Dental College And Research Centre,Nanded

[3]Principal & HOD,Department of Orthodontics & Dentofacial Orthopedics,Sinhgad Dental College & Hospital

[4]Professor & Vice Principal,Department of Orthodontics & Dentofacial Orthopedics

Sinhgad Dental College & Hospital

[5]Associate Professor,Department of Orthodontics & Dentofacial Orthopedics ,D.Y. Patil Dental School, Pune

[6]HOD and Professor,Department of Orthodontics & Dentofacial Orthopedics ,D.Y. Patil Dental School, Pune

***Corresponding Author**

Dr. Abdulrehman Irfan Foujdar

Assistant Professor,Department of Orthodontics & Dentofacial Orthopedics,D.Y. Patil Dental School, Pune

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ABSTRACT

Background: orthodontic mini implants are widely used nowadays in orthodontic practices. It is made up of various materials, due to its advantage of greater anchorage control and better patient compliance they play a pivotal role in orthodontic treatments. Primary stability of these mini implants at different angulations is tested in this study.

Aim & Objective- The objective of this study is to assess and compare the primary stability of self-drilling orthodontic titanium mini-implants (Modern Orthodontics) inserted at various angles into polyurethane bone blocks using a pull-out test.

Material & Methods- 24 new orthodontic titanium mini-implants having diameter and length of 1.6 x 8 mm were purchased and inserted in polyurethane foam bone blocks simulating cortical and cancellous bone layers having density of 50 PCF and 40 PCF respectively with help of implant driver manually. Each specimen underwent a pull-out strength test using the Universal Testing Machine at a loading speed of 1 mm/min.

Results- The mean distribution of Pull out Strength for Modern orthodontics inserted in polyurethane bone block at 90^0 and 60^0 was 205.15 ± 5.39 and 241.87 ± 11.59 respectively. A high statistically significant difference was observed in pull out strength at 60^0 and 90^0 angle (P<0.001).

Conclusion- The findings reveal that the pull-out strength at 60° exceeds that at 90°, emphasizing the critical role of the insertion angle in mini-implant stability.

Keywords: *Mini-Implant, Insertion Angle, Pull-Out Test, Polyurethane Block, Orthodontics, Anchorage.*

1. INTRODUCTION

In orthodontic treatment, achieving precise tooth repositioning relies on appropriately applied forces and innovative tools. Orthodontists utilize a variety of advanced devices, incorporating materials like elastics, springs, wires, and metals, to facilitate desired tooth movements efficiently. Through strategic integration of these components, tailored treatment plans are crafted to produce favorable outcomes, enhancing the effectiveness of orthodontic interventions.

Newton's third law states that every action has an equal and opposite response. When pressure is applied on groups of teeth, all of them should move to varying degrees [1,2,3,4]. The reactive pressures created by the appliance system may cause the teeth to move in an undesired fashion since the majority of orthodontic appliances are tooth-borne.

In orthodontics, Proffit describes anchoring as "resistance to undesirable tooth motions." [5] Historical anchorage methods included intra-oral acrylic pads or extra-oral devices like headgear. Challenges arise when anchorage units shift, necessitating precise anchoring to prevent undesired tooth movements. Absolute anchorage, achieved through mini implants, offers predictability, minimal invasiveness, and cost-effectiveness in orthodontic treatment. [6,7] Various sizes of mini-implants are available in which larger mini-implants offer clinical benefits by spreading the force over wider bone areas, reducing bone stress. [8]

The efficacy of implant anchoring relies on primary stability upon insertion, influenced by factors such as quality of bone , design of implant, insertion technique, bone thickness, and angle of insertion. Studies indicate that inclined mini-implants improve contact with cortical bone, enhancing mechanical retention and stability. [9]

Mini-implants can achieve prompt loading with sufficient initial stability, which is vital for success. Factors influencing this stability include patient characteristics, implant design, and clinical technique. [10] Insertion technique, including angle and predrilling, affects primary stability. It has been observed that mini-implants at 60–70 degrees to the bone surface show better stability than those at 90 degrees.[11,12]

In orthodontics, the pull-out test assesses the retention properties of materials or devices, measuring the shear strength of mini-screws in bone specimens. Previous studies have examined pull-out loads to evaluate stability, considering factors like cortical thickness, healing times, and implant orientation in resisting failure.[13]

Previous research has explored factors such as length and diameter about the stability of mini implants, but there's been limited literature available on how insertion angles affects the stability. Therefore, this study aims to evaluate and compare the primary stability of orthodontic titanium mini-implants (Modern Orthodontics) inserted in polyurethane bone blocks at distinct insertion angle i.e $60^0$and 90^0 .

2. MATERIALS AND METHODOLOGY

Inclusion Criteria:

- Newly purchased mini-implants.
- Mini-Implants with 8mm length and 1.6mm diameter.
- Manufactured by Modern Orthodontics.
- Made of titanium alloy.
- Self-drilling mini-implants.

Exclusion Criteria:

- Different dimensions or materials.
- Not manufactured by the specified commercial houses.
- Previously used mini-implants.
- Self-tapping mini-implants.

Study Instruments:

- Implant driver.(Figure 1)
- New 1.6 x 8 mm self-drilling orthodontic titanium mini-implants from Modern Orthodontics. (Figure 2,3)
- Synthetic Bone (Sawbones). (Figure 4)
- Guide Block for 60^0 angle placement. (Figure 5)
- Universal testing machine. (Figure 6)

Study Setting and Design:

This in-vitro study was carried out in the Department of Orthodontics and Dentofacial Orthopedics. Sample size of 24 was obtained (10),A total of new 24 (1.6x8mm) orthodontic, self drilling titanium mini-implants were purchased from Modern Orthodontics. Mini implants made up of different dimensions, materials, not manufactured from same company, previously used, self tapping system was excluded from the study. Armamentarium such as implant driver, synthetic bone, guide block for correct angulation was prepared and kept ready. These implants were conical formed, hexagonal design with small hole at the top for the passage of threads and ligature wires. Based on degree of angulation these implants were subdivided into Group 1A (60^0 angles) and Group 1B (90^0 angles) consisting of 12 each.

Polyurethane foam bone blocks meeting ASTM F-1839-08 standards and simulating the cortical and cancellous bone layer of densities 50 PCF and 40 PCF. Bone block had two layers, 8.5 mm layer of cancellous bone and 1.5 mm of cortical bone. Both the group of twelve mini implants from Modern Orthodontics was inserted in the polyurethane bone block manually at 90^0 and 60^0 angles respectively. (Figure 7,8). Then the bone block was placed under the universal testing machine and was tied with the help of a metal clamp. Afterwards, the implant's head was tied to the universal testing machine's claw to assess the pull-out strength. The reading of the pull-out strength was measured in Newton for each specimen.

Figures

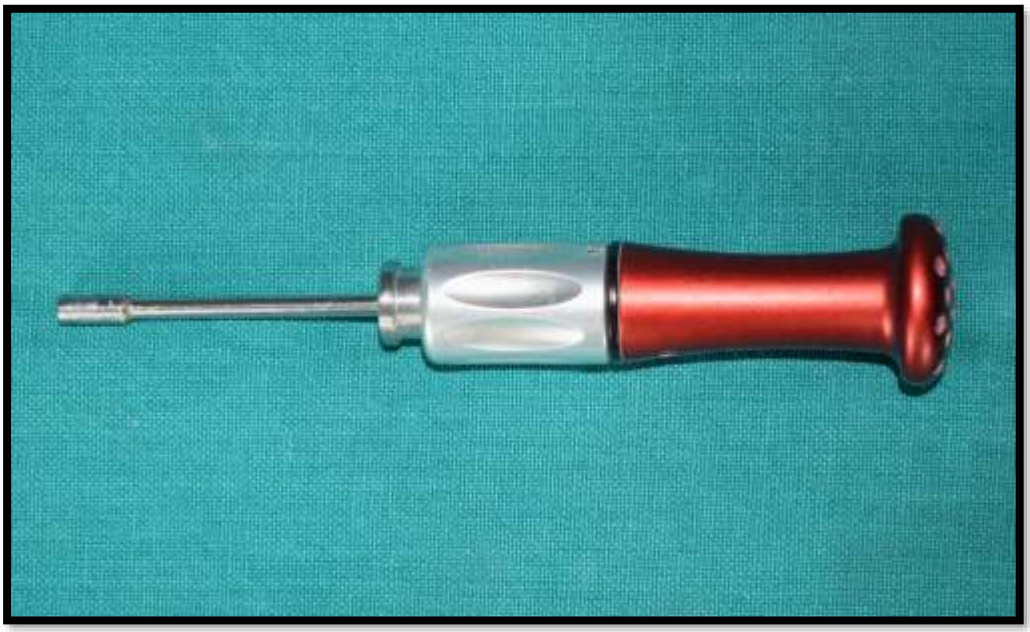


Fig 1: Implant driver

Fig 2: Packaging of Modern Orthodontic implant

Fig 3: Modern Orthodonticimplant

Fig 4: Sawbones polyurethane foam (artificial bone)

Fig 5: Guide block for 60^0angle placement

Fig 6: Universal testing machine

Fig 7: Modern Orthodontic implant places in 40 PCF artificial bone block at 90^{0}

Fig 8: Modern Orthodontic implant places in 40 PCF artificial bone block at 60^{0}

Statistical Analysis-

The data were analyzed using Microsoft Excel and IBM SPSS version 13. Descriptive statistics were applied to determine the mean pull-out strength. ANOVA with post-hoc Tukeys was used to compare pull-out strength among different implant houses and bone block densities. Independent t-tests were used for further comparisons. A 95% confidence interval and p-value <0.05 were considered statistically significant.

3. RESULT

The mean distribution of pull-out strength varied between different titanium mini-implants inserted in polyurethane bone blocks at different insertion angles. At a 90° angle, the pull-out strength was (205.15 ± 5.39). (Table-1) Conversely, at a 60° angle, the mean distribution of the pull-out strength was (241.87 ± 11.59). (Table-2)(Graph)

There was a statistically significant difference in pull-out strength observed at 60° and 90° angles (P<0.001) (Table-3).

Tables

Table 1-Mean Distribution of Pull out Strength of titanium mini- implants from Modern Orthodontics inserted in polyurethane bone blocks at 90°

	N	Minimum	Maximum	Mean	Std. Deviation
90° Modern Orthodontics	12	196.30	214.85	205.1542	5.39935

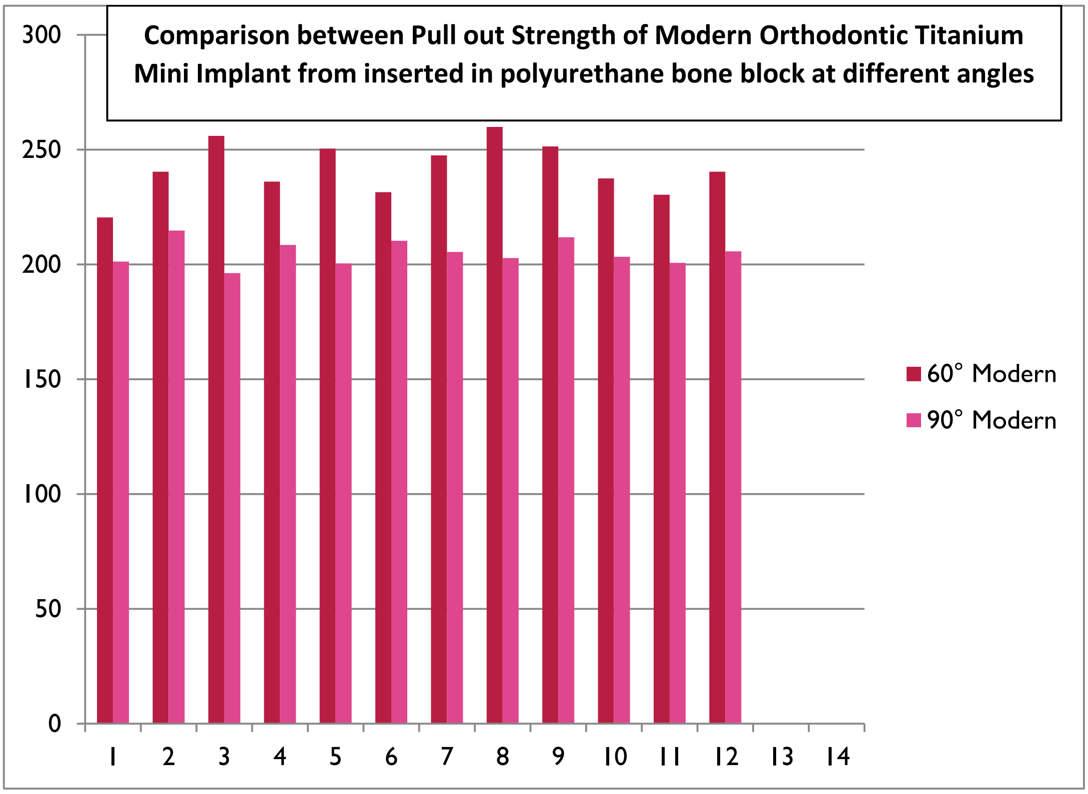
Table 2-Mean Distribution of Pull out Strength of titanium mini- implants from Modern Orthodontics inserted in polyurethane bone blocks at 60°

	N	Minimum	Maximum	Mean	Std. Deviation
60° Modern Orthodontics	12	220.50	260.00	241.8750	11.59617

Table 3-Comparison of Pull out Strength between Modern Orthodontics titanium mini- implants inserted at different angles

Group Statistics							
	Groups	N	Mean	Std. Deviation	Mean Difference	t	P Value
PULL-OUT STRENGHT	90° Modern Orthodontics	12	205.1542	5.39935	-36.72083	- 9.944	.000
	60° Modern Orthodontics	12	241.8750	11.59617			

Graphs



Comparison between Pull out Strength of Modern Orthodontic Titanium Mini Implant from inserted in polyurethane bone block at different angles

4. DISCUSSION

In orthodontics, ensuring the stability of implants or mini-implants is paramount for successful treatment outcomes. Primary stability, characterized by the absence of motion in the bone bed immediately after insertion, is crucial for preventing gradual mobility and potential loss of the device. This stability hinges on various factors, including device attributes, insertion method, and bone quality at the receptor site. In clinical practice, the initial stability of mini-screws is also vital, especially considering the early load applied to them in many patients. Recommendations include replacing inadequately retained mini-implants with thicker devices or altering insertion points to ensure optimal mechanical retention. [14] The insertion angle of implants in the bone is one of the most important factors controlling the primary stability of temporary skeletal anchorage devices.

Haneen et al. [15] employed a pull-out test to assess the primary stability of mini-implants, a common method for evaluating embedding retention characteristics. This test measures the pullout force, indicating the shear strength of mini-screws inserted into bone specimens. Their study investigated the stability of mini-implants at different insertion angles in synthetic bone. The same method was used in this study, where researchers evaluated the pullout strength of mini implants from three different commercial houses at two insertion angles. To assess primary stability, they used artificial bone from Sawbones, chosen for its homogeneity to ensure standardized and reproducible testing, facilitating comparisons across a large sample size. Among various synthetic bone options, polyurethane foam, generated through a polymerization reaction of water and isocyanate, is extensively used in orthopedic experiments due to its closed-cell structure. Approved by the American Society for Testing and Materials (ASTM F-1839-08), polyurethane is recognized as a standard material for testing instruments and oral implants, facilitating comparative evaluations of bone screws. Its uniformity and consistent material properties make rigid polyurethane ideal for conducting relative tests of various medical devices and implants. [16]

Bone mineral density (BMD) values of the mandible range from 0.528 to 0.820 g/cm³, averaging 0.661 g/cm³, while maxillary BMD ranges from 0.31 to 0.55 g/cm³. Cortical bone thickness varies from 1.09 to 2.12 mm in the mandible and 1.59 to 3.03 mm in the maxilla. To simulate both cortical and cancellous bone, a bone block with a 1.5mm cortical layer (density: 0.80g/cm³ or 50 PCF) and an 8.5-mm cancellous layer (density: 0.64g/cm³ or 40 PCF) was used. Thus, customized Sawbones with a 1.5mm cortical layer (density: 50 PCF) and 40 PCF cancellous density were selected for the study. [15]

To the best of our knowledge, vary few literature is available on the comparison of primary stability of different self-drilling orthodontic titanium mini at different insertion angle i.e. 90 degree and 60 degree in synthetic bone block

The present study showed that the pullout strength of group 1 (at 60^0) was significantly higher when compared with the pullout strength of group 2 (at 90^0) for Modern Orthodontics. Similarly, in a study by Araghbidikashani et al. [17], they evaluated the pull-out strength at different insertion angles, which is similar to this study, but they used a different brand of implant and also placed it in the sheep mandible, which is different from our study. The result of the study was statistically significant, and the pullout strength was higher than in this study.

In another study, Meira T.M. et al. [9] evaluated the pull-out strength of mini-implants at different insertion angles (45^0, 60^0 and 90^0) with sizes of 1.6 mm in diameter and 7 mm in length inserted in polyurethane bone blocks. In contrast to our findings, they found that there is no statistically significant difference in the pull-out strength of mini-implants inserted at 60^0 and 90^0, whereas in the current study, there was a statistically significant difference in the pull-out strength of mini-implants. The difference in the result might be due to variations in the sizes and brands of mini implants used in this study.

In a FEM study by Lee J et al. [18], a bone was constructed with a 1mm thickness of cortical bone and a 10mm thickness of cancellous bone The combination-type scheme with cylindrical and tapered parts served as the basis for the miniscrew design (Orlus, Ortholution, Seoul, Korea),and they were inserted at different angles in the bone. When pull-out strength was evaluated in the study, it showed a statistically significant difference in pull-out strength. In the current study, there was also a statistically significant difference in the pull-out strength at different insertion angles

Mohammed et al. [15] in an in-vitro study evaluated the pull-out strength of three different commercially available mini-implants of two different lengths (8mm and 10 mm) and two different diameters (1.6mm and 1.8mm) placed at a 900 insertion angle in the artificial bone block. He found a statistically significant difference between the pull-out strength of 1.6 mm in diameter and 8 mm in length when placed at 90^0 which bears resemblance to the present study. There was a difference observed in the mean pullout strength in both studies as different commercial house implants were used.

The pull out strength at 60 was more than 90 for Modern Orthodontic mini-implants. The explanation for this outcome could be because of the varied mini-implant body design, pitch of the implants, distance between the head and thread.

5. STRENGTHS OF THE STUDY

To our knowledge, this is the first study conducted using these particular bone densities and commercial houses of mini implants to compare the primary stability of mini implants at different insertion angles using pull-out strength.

As synthetic bone was used, the results can be generated for possible comparison, and variation in results due to bone density is avoided.

The head diameter and length of the mini implant are kept the same for all the commercial houses, so bias due to these differences can be avoided, though factors like thread design and shape of the mini implants need to be considered.

6. LIMITATIONS

It cannot be assured that the outcomes of the in-vitro study can be applied to the clinical situation as it was conducted in a laboratory setting, which is its fundamental shortcoming.

If the study is performed in vivo, age, sex, hormonal changes, bone matrix composition, certain disorders, and other variables all affect bone density; thus, they must be taken into account.

Since characteristics such as implant thread design and shape also affect primary stability, they must be taken into consideration.

7. CONCLUSION

In orthodontic therapy, achieving anteroposterior correction while maintaining anchorage is crucial. Mini implants serve as anchorage entities, increasingly utilised to prevent space loss during treatment. However, mini-implant failure due to insufficient primary stability is common, emphasizing the importance of understanding the factors affecting it, such as implant design, insertion technique, and bone quality. This study evaluated the impact of insertion angle on primary stability. Results indicated that a 60° angle yielded greater pull-out strength than 90°, enhancing primary stability. This highlights the significance of the insertion angle and suggests further research is needed in this area.

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