

# Comparative Evaluation of Orthodontic Mini Screws: Bending and Fracture Resistance of Different Commercially Available Stainless Steel Temporary Anchorage Devices

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## ABSTRACT

**Introduction:** Orthodontic treatment often requires precise anchorage to control tooth movement effectively. Temporary anchorage devices (TADs), specifically miniscrews, have emerged as a reliable alternative, offering enhanced stability and control with minimal patient cooperation. While titanium miniscrews are widely used, stainless steel (SS) alternatives are gaining popularity due to their superior torsional strength and cost-effectiveness.

**Aim:** This study aims to evaluate and compare the bending and fracture resistance of two commercially available stainless steel orthodontic miniscrew brands: SK Surgicals and Genius.

**Materials and method:** The study utilized a universal testing machine to apply shear load strength tests to mini-implants of two different diameters (1.3 mm and 1.5 mm) from both brands. A total of 32 mini-implants were tested under controlled conditions at room temperature.

**Results :** 1.5 mm diameter miniscrews exhibited higher fracture resistance than 1.3 mm miniscrews, irrespective of brand. Among the 1.3 mm diameter implants, Genius mini-implants demonstrated a slightly higher fracture resistance ( $119.78 \pm 5.97$  N) compared to SK Surgicals ( $117.38 \pm 4.03$  N), though the difference was not statistically significant. However, for the 1.5 mm diameter implants, Genius mini-implants showed significantly greater fracture resistance ( $135.84 \pm 4.65$  N) than SK Surgicals ( $129.27 \pm 5.95$  N) ( $p < 0.05$ ).

**Conclusion:** These findings suggest that while both brands provide reliable mechanical performance, Genius 1.5 mm implants offer superior fracture resistance, making them a potentially better choice for clinical applications requiring higher load-bearing capacity...

**Keywords:** Orthodontic mini-implants, Temporary Anchorage Devices, Stainless Steel, Bending Resistance, Fracture Resistance, Orthodontic Mechanics

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**Conflict of interest:** None

## INTRODUCTION

The concept of anchorage in orthodontics is crucial for achieving controlled tooth movement while minimizing unwanted side effects. The Greek philosopher Archimedes once said, “Give me a place to stand, and I will move the

earth,” emphasizing the importance of a stable foundation for exerting force. Similarly, orthodontic anchorage plays a pivotal role in ensuring that the desired forces are applied effectively to move teeth while maintaining stability.<sup>1</sup>

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The need for absolute anchorage in orthodontic treatment—where no unwanted movement of the anchorage unit occurs—led to the development of skeletal anchorage systems. Initially, extraoral devices such as headgear were the primary means of achieving absolute anchorage. However, their visible and cumbersome nature made them less acceptable to patients, particularly teenagers and adults. This challenge prompted researchers to explore intraoral alternatives, leading to the introduction of Temporary Anchorage Devices (TADs) or miniscrews.<sup>2</sup>

Orthodontic miniscrews are available in various dimensions, typically ranging from **5.0 mm to 10.0 mm in length** and **1.2 mm to 2.5 mm in diameter**. Generally, **larger diameter miniscrews offer greater resistance to bending and fracture under occlusal forces**, reducing the risk of mechanical failure. However, **smaller diameter miniscrews** are more versatile for placement in narrow interradicular spaces, with a lower risk of damaging adjacent tooth roots.<sup>3</sup>

Unlike conventional dental implants, which require osseointegration, miniscrews rely solely on mechanical retention for stability. This distinction allows them to be used as temporary devices that can be easily inserted and removed without long healing periods. The growing demand for efficient, patient-friendly anchorage solutions has driven advancements in miniscrew materials and designs.<sup>4</sup> Traditionally, **titanium alloy** has been the preferred material for orthodontic mini-implants due to its high biocompatibility, corrosion resistance, and mechanical strength. However, the increasing cost of titanium has led to the exploration of alternative materials such as **stainless steel**, which offers superior torsional strength and lower material costs. Recent studies suggest that **stainless steel mini-implants demonstrate higher bending and fracture resistance compared to titanium counterparts**, making them a viable alternative in clinical practice.<sup>5</sup>

Several companies manufacture orthodontic stainless miniscrews, with **SK Surgical and Genius** being among the commercially available stainless steel brands. Despite the availability of multiple products, **no comparative study has been conducted to evaluate the bending and fracture resistance of these two brands**. Understanding the mechanical properties of different miniscrews is essential for clinicians to make informed decisions regarding material selection based on the specific biomechanical demands of treatment.<sup>6</sup>

### Aim of the Study

To evaluate and compare the bending and fracture resistance of various commercially available stainless steel temporary anchorage devices.

Objectives

1. To evaluate and compare bending resistance of SK Surgicals stainless steel mini-implants of two different diameters[1.5 and 1.3 diameter]
2. To evaluate and compare bending resistance of Genius stainless steel mini-implants of two different diameters[1.5 and 1.3 diameter]
3. To evaluate and compare fracture resistance of SK Surgicals stainless steel mini-implants of two different diameters[1.5 and 1.3 diameter]
4. To evaluate and compare fracture resistance of Genius stainless steel mini-implants of two different diameters[1.5 and 1.3 diameter]

### Materials and Methods

This study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Ahmedabad Dental College & Hospital, and Ahmedabad Textile Industry's Research Association (ATIRA), Ahmedabad after obtaining approval from Ahmedabad Dental College Ethical Committee.

Materials Used:

- 1.3 x 8 mm Genius mini-implants[fig 1]
- 1.5 x 8 mm Genius mini-implants[fig 2]
- 1.3 x 8 mm SK Surgicals mini-implants[fig 3]
- 1.5 x 8 mm SK Surgicals mini-implants[fig 4]



Fig1 [1.3\*8 mm genius ]

fig 2 [ 1.5\*8 mm genius ]



Fig 3 [ 1.3\*8 mm sk surgical]

fig 4 [1.5\*8 mm sk surgical]



Fig 5. Universal testing machine –instron

**INCLUSION CRITERIA**

- Sound miniimplants
- 1.3 and 1.5 diamter ss miniimplants

**EXCLUSION CRITERIA**

- Used miniimplants
- Broken miniimplants
- Blunt miniimplants
- Malformed miniimplants

**METHODOLOGY**

A total of 32 mini-implants were tested, with eight samples in each group. The implants were fixed in an acrylic block and subjected to a tangential load using a Universal Testing

Machine at 1 mm/min crosshead speed. Shear load strength (N) and standard deviations were recorded and analyzed. Statistical analysis was performed using ANOVA and Turkey's HSD tests, with significance set at  $p < 0.05$ .

**SHEAR LOAD STRENGTH**

For each group, 8 different new specimens were tested with a Universal Testing Machine. Each mini implant was inserted in the acrylic block and loaded on lower jaw of the machine. The head (between the endosseous thread and transmucosal collar) was exposed to tangential load with a 1 mm/min crosshead speed fig.6 The load taken to break the

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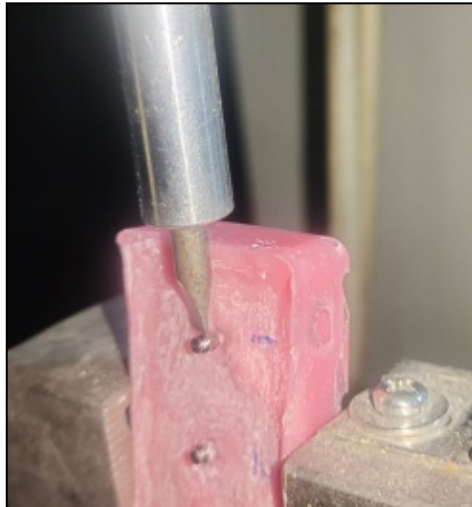
Comparative evaluation of orthodontic mini screws: bending and fracture resistance of different commercially available stainless steel temporary anchorage devices

miniimplants were recorded. The shear load strength (N) and standard deviations were then calculated.

**STATISTICAL ANALYSIS:**

Descriptive statistics, including mean and Standard Deviation, were calculated for all measurements. One Way Analysis of Variance (ANOVA) tests were performed to

determine if any difference in measurements between or within Group I and Group II could be observed. Turkey’s HSD (honestly significance difference) was done for multiple comparisons. The Significance for all the statistical tests was predetermined at  $p < 0.05$



**Fig 6. miniimplant specimen tested for shear load strength**

Results

**Table1:Distribution of study samples of Group1 (Genius1.3diameter)based on Fracture Resistance.**

Group1(Genius1.3d)		
Sample No	MaxLoad(N)	Mean±SD(MPa)
1	129.55	119.78 ± 5.97
2	122.21	
3	118.84	
4	110.09	
5	113.67	
6	120.81	
7	119.4	
8	123.65	

SD:StandardDeviation,Descriptivestatisticsapplied

**Table 1 shows the distribution of study samples of Group 1 (Genius 1.3d)based on Fracture Resistance. The mean Fracture Resistance among Group 1 was 119.78 ± 5.97 N.**

**Table2:Distribution of study samples of Group1 (SK Surgicals1.3diameter) based on Fracture Resistance.**

Group1(SKSurgicals1.3d)		
Sample No	MaxLoad(N)	Mean±SD(MPa)
1	109.41	
2	119.23	
3	116.17	

Comparative evaluation of orthodontic mini screws: bending and fracture resistance of different commercially available stainless steel temporary anchorage devices

4	115.87	117.38 ± 4.03
5	116.62	
6	123.39	
7	118.89	
8	119.52	

**Table 2** shows the distribution of study samples of Group 1 (SK Surgicals 1.3d) based on Fracture Resistance. The mean Fracture Resistance among Group1(SKSurgicals1.3d)was117.38 ± 4.03 N.

**Table3:**Distribution of study samples of Group2 (Genius1.5 diameter ) based on Fracture Resistance.

Group2(Genius1.5d)		
Sample No	MaxLoad(N)	Mean±SD(MPa)
1	127.44	135.84 ± 4.65
2	142.49	
3	139.66	
4	137.45	
5	132.58	
6	137.29	
7	133.34	
8	136.51	

SD: Standard Deviation, Descriptive statistics applied

**Table 3** shows the distribution of study samples of Group 2 (Genius 1.5d)based on Fracture Resistance. The mean Fracture Resistance among Group 2 (Genius 1.5d) was 135.84 ± 4.65 N.

Table4:Distribution of study samples of Group2 (SKSurgicals1.5diameter )based on Fracture Resistance.

Group2(SKSurgicals1.5d)		
Sample No	MaxLoad(N)	Mean±SD(MPa)
1	122.29	129.27 ± 5.95
2	121.57	
3	136.92	
4	129.51	
5	126.33	
6	127.62	
7	133.34	
8	136.60	

Comparative evaluation of orthodontic mini screws: bending and fracture resistance of different commercially available stainless steel temporary anchorage devices

SD: Standard Deviation ,Descriptive statistics applied

Table 4 shows the distribution of study samples of Group 2 (SK Surgicals 1.5d) based on Fracture Resistance. The mean Fracture Resistance among Group2 (SKSurgicals1.5d) was

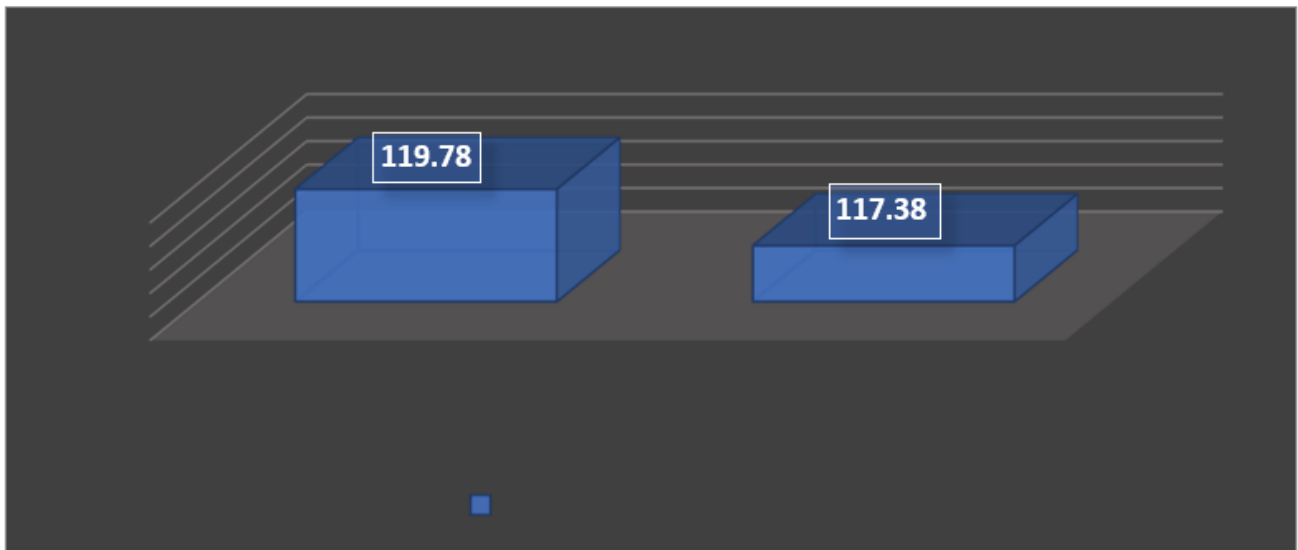
129.27 ± 5.95 N.

Table5: Distribution of study samples of Group 1 based on Fracture Resistance.

Group1								
Sr. No	Implant Sample	Implant Diameter	N	Mean Fracture Resistance (N)± SD	Mean Difference	Standard Error	t Value	P Value
1	Genius	1.3 mm	8	119.78 ± 5.97	2.39	2.81	0.851	0.423**
2	SK Surgicals	1.3 mm	8	117.38 ± 4.03				

Paired Sample- Test Applied, SD :Standard Deviation

Graph-1: Distribution of study samples of Group 1 based on Fracture Resistance.



Tables 5 and Graph 1 show the distribution of study samples of Group 1 based on Fracture Resistance. The mean Fracture Resistance of the Implant from Genius with a diameter of 1.3 mm was 119.78 ± 5.97 N. The mean Fracture Resistance of the Implant from SK Surgicals with a diameter of 1.3 mm was 117.38 ± 4.03 N. Statistically, No significant difference was observed among Group 1 regarding Fracture Resistance between the two companies (Genius 1.3d & SK Surgicals 1.3d) Implants (p< 0.05\*).

**Table 6: Distribution of study samples of Group 2 based on Fracture Resistance.**

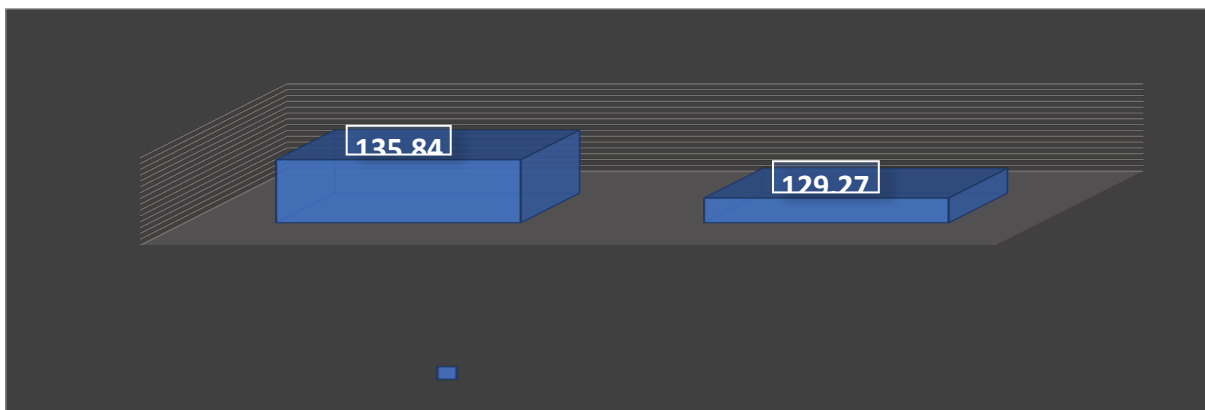
Comparative evaluation of orthodontic mini screws: bending and fracture resistance of different commercially available stainless steel temporary anchorage devices

Group 2								
Sr. No	Implant Sample	Implant Diameter	N	Mean Fracture Resistance (N) ± SD	Mean Difference	Standard Error	t Value	P Value
1	Genius	1.5 mm	8	135.84 ± 4.65	6.57	2.39	2.74	0.029*
2	SK Surgicals	1.5 mm	8	129.27 ± 5.95				

Independent Sample t-Test Applied, SD: Standard Deviation

Graph 2: Distribution of study samples of Group 2 based on Fracture Resistance.

Tables 6 and Graph 2 show the distribution of study samples of Group 2 based on Fracture Resistance. The mean Fracture



Resistance of the Implant from Genius with a diameter of 1.5 mm was  $135.84 \pm 4.65$  N. The mean Fracture Resistance of the Implant from SK Surgicals with a diameter of 1.5 mm was  $129.27 \pm 5.95$  N. A statistically significant difference was observed among Group 2 regarding Fracture Resistance between the two companies (Genius 1.5d & SK Surgicals 1.5d) Implants ( $p < 0.05^*$ ).

Table-7a: Distribution of study samples based on Groups and Fracture Resistance.

Implant	Diameter	Mean Fracture Resistance (N) ± SD	F value	P value
Genius	1.3 d	119.78 ± 5.97	21.49	0.001 *
SK Surgicals	1.3 d	117.38 ± 4.03		
Genius	1.5 d	135.84 ± 4.65		
SK Surgicals	1.5 d	129.27 ± 5.95		

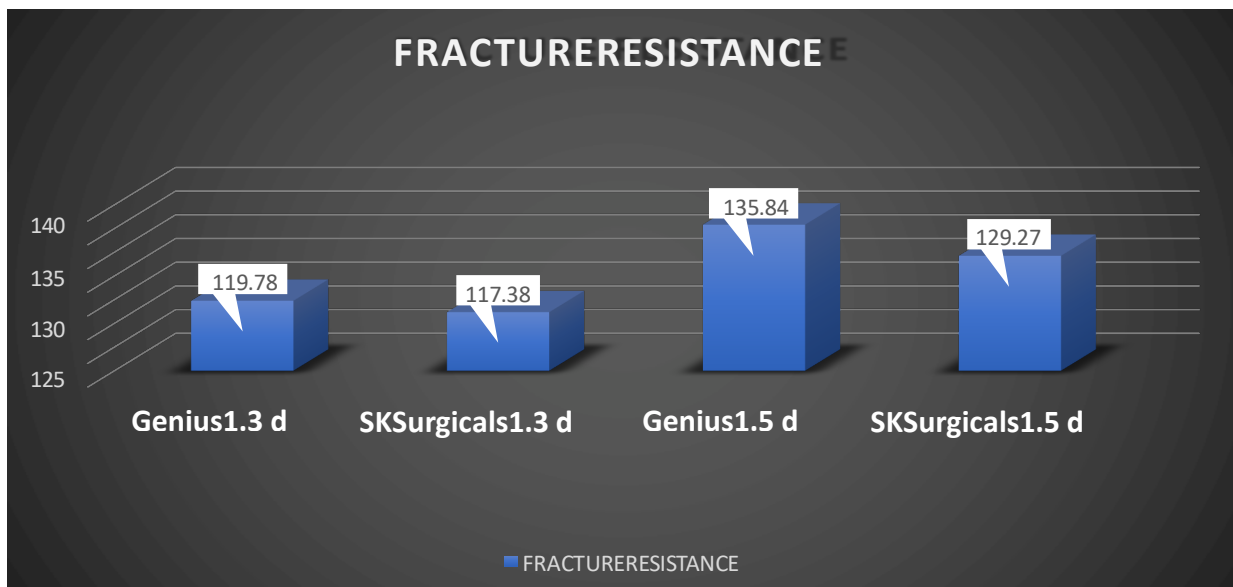
ANOVA Applied, Level of Significance:  $\leq 0.05$ , Statistically Significant \*, Statistically Non Significant \*\*

Table-7b: Distribution of study samples based on Groups and Fracture Resistance.

Mean	Sum of Squares	df	Mean Square	F	Sig.

Between Groups	1758.32	3	586.108	21.49	0.001*
Within Groups	763.54	28	27.269		
Total	2521.86	31			

**Graph-3: Distribution of study samples based on Groups and Fracture Resistance.**



**Tables 7a, 7b and Graph 3** show the distribution of study samples based on Fracture Resistance. The mean Fracture Resistance of the Implant from Genius with a diameter of 1.3 mm was  $119.78 \pm 5.97$  N. The mean Fracture Resistance of the Implant from SK Surgicals with a diameter of 1.3mmw as  $117.38 \pm 4.03$  N. The mean Fracture Resistance of the Implant from Genius with a diameter of 1.5 mm was  $135.84 \pm 4.65$  N. The mean Fracture Resistance of the Implant from SK Surgicals with a diameter of 1.5 mm was  $129.27 \pm 5.95$  N. A statistically significant difference was observed between these implants regarding Fracture Resistance (Genius 1.3d, SK Surgicals 1.3d, Genius 1.5d & SK Surgicals 1.5d) ( $p < 0.05^*$ ).

#### DISCUSSION

- The mean fracture resistance of Genius 1.3 mm was  $119.78 \pm 5.97$  N, while SK Surgicals 1.3 mm had  $117.38 \pm 4.03$  N.
- The mean fracture resistance of Genius 1.5 mm was  $135.84 \pm 4.65$  N, whereas SK Surgicals 1.5 mm had  $129.27 \pm 5.95$  N.
- Statistically significant differences were observed in the 1.5 mm diameter group ( $p < 0.05$ ), indicating superior fracture resistance in Genius mini-implants.

This study aimed to evaluate and compare the bending and fracture resistance of stainless steel orthodontic mini-implants manufactured by Genius and SK Surgicals. The findings have significant clinical implications, offering insights into the performance and selection criteria for mini-implants based on mechanical properties.<sup>7</sup>

In the present report, miniscrews have been tested in air for tangential load as this vector of force is the same to which miniscrews are subjected when employed for unconventional orthopedic uses.

Moreover, during these applications, forces generated at screw collar are significantly higher than those generated when the screw is used for conventional orthodontic anchorage. Therefore, higher resistance to plastic deformation and fracture is needed. The collar region can be considered the weak point of the whole screw, and this is the main reason for which the bending and fracture force have been applied at this specific point of the miniscrews in the present investigation.<sup>8</sup>

Wilmes *et al.*, conducted an *in vitro* study and evaluated the threshold torque values resulting in the fracture of various mini-implant types and diameters. They concluded to use mini-implants with a larger diameter. If mini-implants are inserted at a site with high bone quality, pre-drilling seems reasonable even for self-drilling mini-implants to minimize the risk of mini-implant fracture.<sup>9</sup>

In a study by Puls GL, *et al.* they aimed to compare the insertion torque (IT), flexural strength (FS) and surface alterations between stainless steel (SS-MIs) and titanium alloy (Ti-MIs) orthodontic mini-implants. They concluded that SS-MIs offer sufficient stability and exhibit greater mechanical strength, compared to Ti-MIs when inserted into higher density bone.<sup>10</sup>

Miniscrews are marketed with different lengths and diameters. During clinical practice, long screws ( $\geq 8$  mm) present significantly higher success rates than the rates obtained with shorter ones. However, it has been demonstrated that as the length of the miniscrew that is in contact with the bone is increased, the amount and pattern of stress distribution in the cortical bone and the miniscrew do not change significantly. For this reason, the miniscrew length has not been considered as a variable in the present investigation.<sup>11</sup>

In our study, all of the screws that were evaluated were new. No tests have been conducted on retrieved mini implants. In dentistry, some materials are reused after disinfection and sterilization procedures. *In vitro* and *in vivo* studies demonstrated the reliability of many reconditioned orthodontic devices. In addition, miniscrews have been tested after recycling, showing that morphological changes mainly occurred at the screw tip.<sup>12</sup>

The cortical bone penetration success rate of recycled screws has been reported to be lower than that of unused screws<sup>13</sup>. On the other hand, no significant difference in the bone–miniscrew contact ratio has been found between new and used miniscrews. Moreover, also fracture torque has been showed to be not influenced by recycling protocols. However, future reports are needed in order to test the bending and fracture loads for retrieved miniscrews before suggesting clinical use.

#### **Bending and Fracture Resistance Across Groups**

The results demonstrated that:

Genius mini-implants consistently exhibited higher fracture resistance than SK Surgical mini-implants in both diameters tested (1.3 mm and 1.5 mm).

The mean fracture resistance of 1.5 mm Genius mini-implants ( $135.84 \pm 4.65$  N) was significantly greater than that of 1.5 mm SK Surgical mini-implants ( $129.27 \pm 5.95$  N). This statistical significance highlights the potential advantage of Genius implants in clinical scenarios requiring higher load resistance.

For the 1.3 mm diameter group, the fracture resistance difference between Genius ( $119.78 \pm 5.97$  N) and SK Surgical ( $117.38 \pm 4.03$  N) mini-implants was not statistically significant. This suggests that diameter may play a more critical role in load-bearing capability than brand-specific differences at smaller dimensions.

#### **Effect of Diameter on Mechanical Performance**

The study corroborates prior findings that increasing the diameter of mini-implants enhances their mechanical strength:

Across both brands, 1.5 mm mini-implants demonstrated superior fracture resistance compared to their 1.3 mm counterparts.

The larger cross-sectional area of 1.5 mm implants contributes to their increased resistance to bending and fracture under load.

#### **Material Considerations**

Stainless steel has been widely recognized for its superior torsional strength compared to titanium alloys. The findings of this study further support the mechanical reliability of stainless steel mini-implants, particularly for applications demanding high resistance to deformation and fracture.<sup>14</sup>

#### **Clinical Relevance**

**Applicability in Orthodontics:** Mini-implants with higher fracture resistance are particularly advantageous in regions of dense bone or when subjected to high forces during orthodontic treatment.

**Selection Criteria:** While both Genius and SK Surgical mini-implants provide adequate mechanical performance, the preference for Genius implants in situations requiring greater load tolerance (especially in 1.5 mm diameter) is justified based on the observed results.

**Patient-Specific Needs:** The selection of implant diameter and brand should consider anatomical constraints, expected load forces, and patient-specific requirements.

#### **Future Directions**

Comparative studies including titanium and hybrid material mini-implants could provide a more comprehensive understanding of material performance.

Investigating the long-term performance of these implants under dynamic loading and *in vivo* conditions would enhance the clinical applicability of the findings.

Expanding the scope to include patient-specific anatomical and biomechanical factors, such as bone density and implant positioning, would refine implant selection criteria.

## CONCLUSION

This study concludes that Genius stainless steel mini-implants exhibit higher bending and fracture resistance than SK Surgicals mini-implants, particularly with the 1.5 mm diameter. These findings are significant for clinical decision-making, guiding orthodontists in selecting mini-implants with superior mechanical properties for optimal treatment outcomes.

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