EFFECT OF DUAL-THREAD, LENGTH AND INSERTION ANGLE IN ORTHODONTIC MINISCREWS PRIMARY STABILITY - AN *IN VITRO* STUDY

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Abstract

The aim of the study was to determine the effect of dual-thread, length, and insertion angle on orthodontic miniscrew primary stability, and define the best shape and diameter of miniscrew that can be used to confer the best stability.

The study sample consisted of 48 orthodontic miniscrews made of Ti-6Al-4V alloy with 2 shapes, standard and dual-thread, 2 lengths were used: 7 and 8mm. Miniscrews were inserted according to 2 angles (45°, 90°) with respect to bone surface. The maximum insertion torque, the Periotest value and the maximum removal torque were measured.

The results showed that the maximum insertion and removal torque were statistically higher while the Periotest values were statistically lower when using the dual-thread, 8mm length, and 90° insertion angle than the regular shape, 7mm length and 45° insertion angle ($p < 0.01$).

Keywords: Periotest - miniscrew - insertion torque - dual-thread - primary stability.

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EFFET DU DOUBLE FILETAGE, DE LA LONGUEUR ET DE L'ANGLE D'INSERTION DES MINISCREWS ORTHODONTIQUES STABILITÉ PRIMAIRE - UNE ÉTUDE *IN VITRO*

Résumé

L'objectif de l'étude était de déterminer l'effet du double pas de vis, de la longueur et de l'angle d'insertion sur la stabilité primaire des minivis orthodontiques et de définir la forme et le diamètre du minivis qui confèrent la meilleure stabilité.

L'échantillon de l'étude était compris de 48 minivis orthodontiques en alliage Ti-6Al-4V. Deux formes et deux longueurs ont été utilisées. Les minivis ont été insérés suivant deux angles (45° et 90°) par rapport à la surface de l'os. Le couple d'insertion maximal, la valeur du Periotest et le couple de désinsertion maximal ont été mesurés.

Les résultats ont montré que les valeurs des couples d'insertion et de désinsertion étaient statistiquement plus élevées tandis que les valeurs du Periotest étaient statistiquement plus faibles lors de l'utilisation du minivis à double pas de vis, de longueur 8 mm et inséré perpendiculairement à la surface de l'os ($p < 0.01$).

Mots-clés: minivis orthodontique – Périotest – stabilité primaire.

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Introduction

Anchorage has been a challenge since the introduction of fixed appliances in orthodontics. Typically, orthodontic movement of a tooth is anchored by a large group of teeth so as to minimize undesired displacements of anchoring teeth. Adequate anchorage becomes difficult when posterior teeth are missing [1]. Intra - and extra -oral auxiliary devices can be used to assist movement, but the effectiveness of these measures is dependent upon the level of patient cooperation [1].

Conventional titanium implants have emerged as an excellent alternative to traditional orthodontic anchorage methodologies, mainly when anchorage dental elements are insufficient in quantity or quality [2].

The entry of skeletal anchorage devices to the clinical orthodontic enabled orthodontic specialists to overcome many of the difficulties that occur during orthodontic treatment as controlling anchorage, the need for patient cooperation, and posterior tooth loss [3, 4].

Titanium miniscrews (1.2 mm in diameter and 6.0 mm in length) for orthodontic anchorage were proposed by Kanomi [5]. Their major advantages include small size, minimal anatomic limitation for placement, lower medical cost, simpler implantation and removal surgery, less discomfort after implantation, and the possibility of immediate or early loading; moreover, miniscrews can provide effective anchorage that is not dependent on patient compliance [6].

Because these devices are used for specific -mainly short- time periods, they mostly rely on mechanical retention and do not always osseointegrate [7].

The success of any implant in providing definitive anchorage depends on its stability [8]. The stability of miniscrews consists of primary and secondary stability.

The primary stability is believed to result from mechanical interlock with alveolar cortical bone [9].

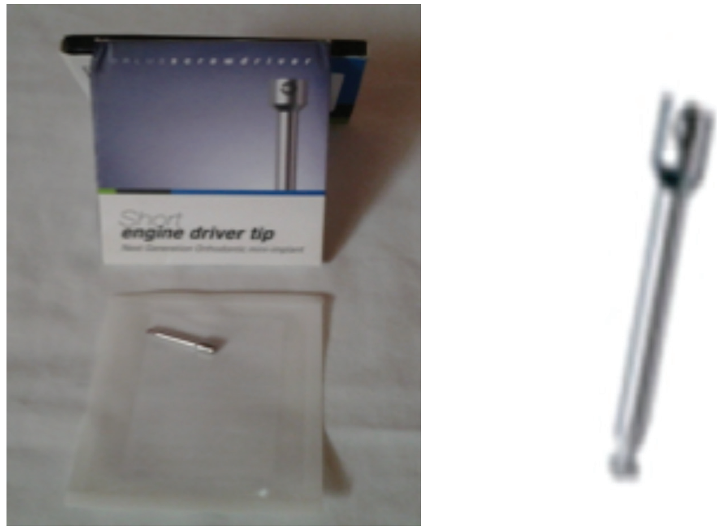

Fig. 1: Accessory help to compose the miniscrew on the handpiece of the implantation system.

Many researchers have investigated the risk factors for failure of miniscrews to improve the success rate. They found that the primary stability of miniscrews is related to the mechanical characteristics of the interface between the miniscrews and bone in relation to factors such as bone quality and quantity, and screw diameter, length, and design [10]. Researchers concluded that stability can be enhanced by maximizing the interlocking surface area (SA) between the bone and implant, which can be achieved by increasing diameter, increasing length and adding threading [11-13].

For orthodontic purposes, a miniscrew should be small enough to allow ready placement in any area of the alveolar bone, including the apical bone, thus enabling various orthodontic movements [13]. The most frequently used insertion site is the alveolar ridge. However, tooth injury represents a risk that shouldn't be underestimated.

To avoid root damage, Park et al. introduced an oblique instead of a perpendicular miniscrew insertion because more space was available near the apical region [14-16].

The stability of implants can be evaluated using the mobility test, the resonance frequency analysis, and the torque analysis [17].

Placement torque is the measurement of the resistance at the screw-bone interface; it reflects the level of bone deformational strain caused by the miniscrew [18]. Although insertion torque analysis was developed as a method to assess stability and supportive capacity of the implant [19], the insertion torque may have a low relationship to stability; removal torque can be more useful to test the mechanical stability of implants [20].

In addition, the Periotest is used to evaluate and test the periodontal tissues, evaluate the implant osseointegration throughout the various stages of the implant procedure, and it is one of the reliable methods to estimate implant stability [21].

The aim of the present study was to determine the effect of dual-thread, length, and insertion angle on the orthodontic miniscrew primary stability, and define the best shape and diameter of miniscrew that can be used to obtain the best stability.

Materials and methods

The research material consisted of:

- Miniscrews (Yesanchor Mini Implant, Ortholution Co., Korea).
- Accessory help to compose the miniscrew on the handpiece of the implantation system (Orlus

Density		Compressive strength (MPa)		Tensile strength (MPa)		Shear strength (MPa)	
(pcf)	(g/cc)	Strength	Modulus	Strength	Modulus	Strength	Modulus
30	0.48	20	533	11	640	8 > 9	122

*pcf: per cubic foot.
Table 1: Mechanical properties of the solid rigid polyurethane foam (Sawbones) for insertion of the orthodontic miniscrews.

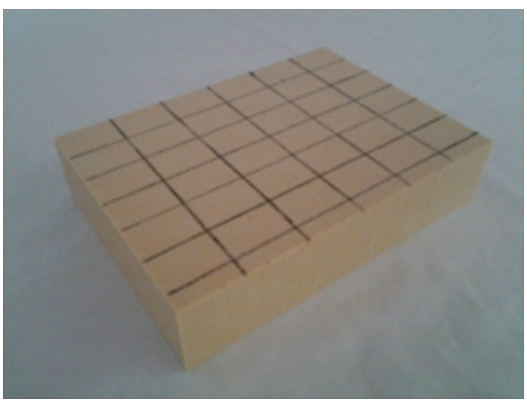

Fig. 2: Sawbones.

Fig. 3: NSK Surgic XT.

Fig. 4: Periotest device.

Screwdriver, Ortholution Co., Korea). (Fig. 1).

- Artificial bone: solid rigid polyurethane foam (Sawbones, Pacific Research Laboratories Inc, Vashon, Wash); homogeneous 30 pounds per cubic foot (pcf) density (Table 1 [21]; Fig. 2).

- The implantation system (NSK Surgic XT, NSK, Japan) (Fig. 3).

- The Periotest device (Periotest, Medizintechnik Gulden, Germany) (Fig. 4).

The sample consisted of 48 miniscrews made with Ti-6Al-4V alloy. Two shapes (regular and dual-thread) were inserted (Fig. 5) with 2 lengths (7-8 mm) and one diameter (1.6 mm).

The miniscrews were inserted along 2 axes, vertical on the Sawbones surface and 45° angled on the same surface.

The miniscrews were divided into 8 groups:

Group 1: Regular shape, length 7 mm, insertion angle 90°.

Group 2: Dual-thread shape, length 7 mm, insertion angle 90°.

Group 3: Regular shape, length 8 mm, insertion angle 90°.

Group 4: Dual-thread shape, length 8 mm, insertion angle 90°.

Group 5: Regular shape, length 7 mm, insertion angle 45°.

Group 6: Dual-thread shape, length 7 mm, insertion angle 45°.

Group 7: Regular shape, length 8 mm, insertion angle 45°.

Group 8: Dual-thread shape, length 8 mm, insertion angle 45°.

The miniscrews were inserted into the Sawbones with 20 rpm rotational speed. We used the miniscrew nick as a standard stopper because soft tissues thickness differs among humans. The miniscrews were either perpendicular to the Sawbones surface or beveled with a 45° insertion angle (Fig. 6).

- Three tests were applied:

- The maximum insertion torque (MIT).

- The Periotest.

- The maximum removal torque (MRT).

When recording the Periotest values, the distance separating the device head and the miniscrew was 0.6 to 2 mm. Measurements were repeated three times and the results' mean was considered.

Statistical analysis

Two- way analysis of variance with three factors (shape, angle, length) was conducted followed by multiple comparison test. The SPSS software (version 18) was used to analyze the

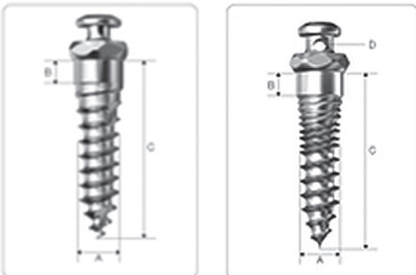

Fig. 5a - 5b: The dual-thread and normal shape of the miniscrew.

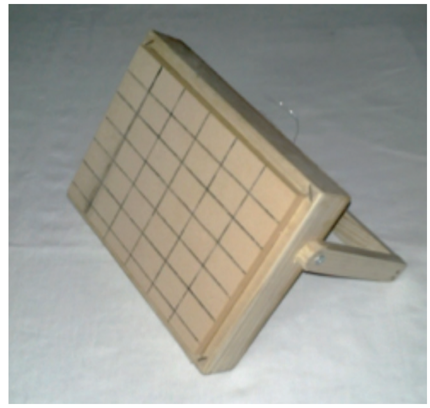

Fig. 6: A 45° bevel base.

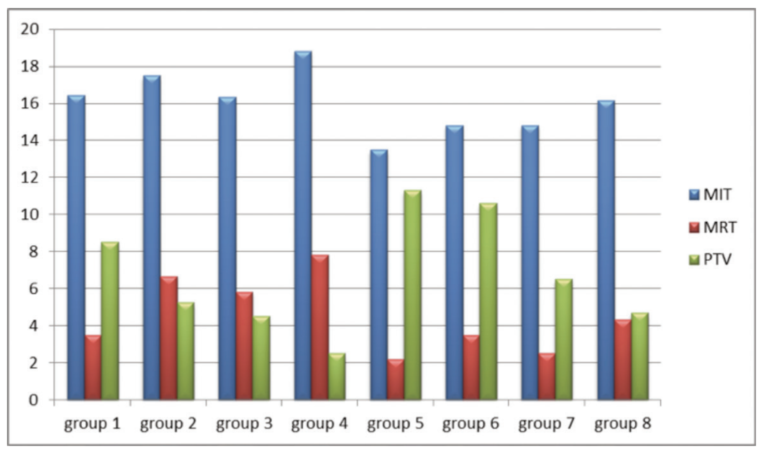

Fig. 7: Means of MIT, MRT and PTV for the 8 groups.

results. The level of significance was set at p-value = 0.05.

Results

When evaluating the MIT values, the three studied variables, i.e. shape, length and diameter of miniscrews influenced significantly the obtained mean and standard deviation values ($p < 0.05$).

Also, there was an effect of three variables on PTV ($p < 0.05$). An intercept effect between shape and angle of insertion on PTV was noted ($p < 0.05$).

Statistically significant differences in MIT values were found when the shape of miniscrews was considered; those differences were in favor of the dual-thread shape that confered greater stability ($p <0.01$) (Table 2).

Also, when the length of miniscrews was considered, statistically significant differences in MIT values among most of the groups were in favor of the length of 8mm ($p <0.01$). However, in the groups 1 and 3, the difference was not statistically significant (Table 3).

Concerning the insertion angle of the miniscrews, statistically significant differences were found among the groups; those differences were in favor of the insertion angle value of 90° which gave greater stability ($p < 0.01$) (Table 4).

When evaluating the PTV values, statistically significant differences between most of the groups were obtained depending on the shape of the miniscrews. Those differences were in favor of the dual-thread shape which gave greater stability ($p < 0.01$). However, between groups 5 and 6, the difference was not statistically significant (Table 5).

Statistically significant differences were obtained in PTV values when the length of miniscrews was considered. Those differences were in favor of the length of 8mm ($p < 0.01$) (Table 6).

Also, when the insertion angle of miniscrews was considered, statistically significant differences were noted; those differences were in favor of the insertion angle 90° which gave greater stability ($p < 0.01$) (Table 7).

Concerning the shape of miniscrews, the differences in MRT values between the groups were statistically significant; the differences were in favor of the dual-thread shape ($p <0.01$) (Table 8).

Additionally, statistically significant differences were obtained between most of the groups when the length of the miniscrews was evaluated. The differences were in favor of the length of 8 mm ($p < 0.05$). Between

Groups	Mean ± SD (N/cm)	F	Sig.	T	Df	p-value
1	16.42 ±0.669	1.189	0.287	-3.336	10	0.003 **
2	17.50 ±0.905				20.256	
3	16.33 ±0.778	6.972	0.015	-6.708	10	0.000 **
4	18.83 ±1.030				20.477	
5	13.50 ±0.905	2.532	0.126	-3.370	10	0.003 *
6	14.83 ±1.030				21.640	
7	14.83 ±0.577	20.439	0.000	-3.912	10	0.001 **
8	16.17 ±1.030				17.293	

* p < 0.05; ** p < 0.01.
SD: Standard deviation.
Table 2: Effect of the shape of miniscrews on the MIT.

Groups	Mean ± SD (N/cm)	F	Sig.	T	df	p-value
1	16.42 ±0.669	0.027	0.871	0.281	10	0.781
3	16.33 ±0.778				21.509	
2	17.50 ±0.905	2.532	0.126	-3.370	10	0.003 **
4	18.83 ±1.030				21.640	
5	13.50 ±0.905	5.436	0.029	-4.304	10	0.000 **
7	14.83 ±0.577				18.687	
6	14.83 ±1.030	0.000	1.000	-3.171	10	0.004 **
8	16.17 ±1.030				22.000	

* p < 0.05; ** p < 0.01.
Table 3: Effect of the length of miniscrews on the MIT.

Groups	Mean ± SD (N/cm)	F	Sig.	T	df	p-value
1	16.42 ± 0.669	1.189	0.287	8.983	10	0.000 **
5	13.50 ± 0.905				20.256	
2	17.50 ± 0.905	2.532	0.126	6.739	10	0.000**
6	14.83 ± 1.030				21.640	
3	16.33 ± 0.778	1.497	0.234	5.361	22	0.000**
7	14.83 ± 0.577				20.290	
4	18.83 ± 1.030	0.000	1.000	6.343	10	0.000**
8	16.17 ± 1.030				22.000	

* p < 0.05; ** p < 0.01.
Table 4: Effect of the insertion angle of miniscrews on the MIT.

Groups	Mean	F	Sig.	T	df	p-value
1	8.5167 ± 0.369	23.413	0.000	14.385	10	0.000 **
2	5.250 ± 0.695				16.745	
3	4.5167 ± 1.41475	78.125	0.000	3.001	10	0.007 **
4	2.500 ± 1.849				20.593	
5	11.300 ±1.1724	14.440	0.001	1.935	10	0.066
6	10.600 ± 0.4431				14.080	
7	6.500 ± 1.2225	727.375	0.000	4.826	10	0.000 **
8	4.700 ± 0.418				13.535	

* $p < 0.05$; ** $p < 0.01$.
Table 5: Effect of the shape of miniscrews on the Periotest values.

Groups	Mean ± SD	F	Sig.	T	df	p-value
1	8.5167 ± 0.3689	231.559	0.000	9.477	10	0.000 **
3	4.5167 ± 1.4147				12.489	
2	5.2500 ±0.695	425.681	0.000	4.823	10	0.000 **
4	2.5000 ± 1.849				14.046	
5	11.3000 ± 1.1724	1.136	0.298	9.817	10	0.000 **
7	6.5000 ± 1.2225			9.817	21.962	
6	10.6000 ± 0.4431	0.268	0.610	33.559	10	0.000 **
8	4.7000 ± 0.418			33.559	21.924	

* $p < 0.05$; ** $p < 0.01$.
Table 6: Effect of the length of miniscrews on the PTV.

Groups	Mean	F	Sig.	T	df	p-value
1	8.517 ± 0.36886	18.464	0.000	-7.845	10	0.000 **
5	11.300 ± 1.1724				13.157	
2	5.250 ± 0.6948	13.470	0.001	-22.490	10	0.000 **
6	10.600 ± 0.4431				18.679	
3	4.517 ± 1.4147	17.513	0.000	-3.674	10	0.001 **
7	6.500 ± 1.2225				21.547	
4	2.500 ±1.8488	1681.0	0.000	-4.021	22	0.001 **
8	4.7000 ± 0.4178				12.120	

* $p < 0.05$; ** $p < 0.01$.
Table 7: Effect of the insertion angle of miniscrews on the PTV.

Groups	Mean ± SD (N/cm)	F	Sig.	T	Df	p-value
1	3.50 ± 0.522	16.844	0.000	-9.841	10	0.000 **
2	6.67 ± 0.985				16.734	
3	5.83 ± 1.030	0.000	1.000	-4.757	10	0.000 **
4	7.83 ± 1.030				22.000	
5	2.17 ± 1.030	2.532	0.126	-3.370	10	0.003 **
6	3.50 ± 0.905				21.640	
7	2.50 ± 0.905	0.957	0.338	-5.322	10	0.000 **
8	4.33 ± 0.778				21.523	

* $p < 0.05$; ** $p < 0.01$.
Table 8: Effect of the shape of miniscrews on the MRT.

groups 5 and 7, the difference was not statistically significant (Table 9).

Also, statistically significant differences in MRT values were observed when considering the insertion angle; those differences were in favor of the insertion angle value of 90° ($p < 0.01$) (Table 10).

The Pearson correlation showed an inverse strong relationship between the PTV and the MIT and the MRT values. The relationship reached -0.604 with the MIT and -0.622 with the MRT ($p < 0.01$). Also there was a very strong positive relationship between the MIT and the MRT values reaching 0.936 ($p < 0.01$) (Table 11).

Discussion

Effect of the shape on the primary stability of miniscrews

In the present study, 2 different shapes of the miniscrew were used; the regular and the dual thread shapes.

The regular shape is tapered and has equal threads on the part of miniscrew inserted in the bone; the dual-thread shape is also tapered but has two types of threads: the cervical part that is placed in the bone includes micro-threads closer to each other than the micro-threads on the remaining two thirds of the miniscrew length.

The goal of this modification was to increase the surface area in contact with the cortical bone.

Our study showed statistically significant differences between the two shapes. These findings were in favor of the dual-thread, modified shape which provided greater stability as reflected by the applied tests, MIT, PTV and MRT.

These results are concordant with those of Kim et al. [17]. The used miniscrews were 1.6 mm in diameter, lengths were 6 and 8 mm, and shapes were conical, cylindrical and dual-threaded. They studied the MIT and the MRT and concluded that the dual-thread shape presented the highest MRT values in all lengths.

Effect of the length on the primary stability of miniscrews

In the present study, we used 2 different lengths (7 and 8 mm). Increasing the length aims to increase the surface area of the part of the miniscrew inserted in the bone. However, this also increases the risk of teeth roots injury or other anatomical structures surrounding the miniscrew insertion site.

Statistically significant differences between the two studied lengths were observed. These findings were in favor of the 8mm length which provided greater stability in most of the tests: the average values of MIT and MRT were greater than those obtained in the 7mm length groups. The average values of the Periotest were smaller in the groups of miniscrews of 8 mm compared to those of 7mm length.

Increasing the length improved the primary stability of miniscrews because it increased the bone-to-miniscrew contact surface, thus increasing friction.

Increasing length helps to resist levering reaction applied on miniscrew during the application of the orthodontic force upon it which seeks to uproot the miniscrew from the bone.

Same results were reported by Jiang et al. [22] who used miniscrews ranging from 6 to 16 mm in length, and between 1 to 2 mm in diameter. They found that when the length exceeds 11 mm, the miniscrews achieved better stability. They also found that the longest length within the safe area is the ideal when choosing miniscrews [22].

Effect of the insertion angle on primary stability of miniscrews

In the present study, miniscrews were inserted either perpendicular or beveled with a 45° angulation. Angled insertion of 45° with respect to the bone surface aims to avoid as much as possible the adjacent dental roots and

Groups	Mean ± SD (N/cm)	F	Sig.	T	Df	p-value
1	3.50 ± 0.522	90.829	0.000	-7.000	10	0.000 **
3	5.83 ± 1.030				16.306	
2	6.67 ± 0.985	0.607	0.444	-2.836	10	0.010 *
4	7.83 ± 1.030				21.956	
5	2.17 ± 1.030	2.532	0.126	-0.842	10	0.409
7	2.50 ± 0.905				21.640	
6	3.50 ± 0.905	0.957	0.338	-2.419	10	0.024 *
8	4.33 ± 0.778				21.523	

* p < 0.05; ** p < 0.01.
Table 9: Effect of the length of miniscrews on the MRT.

Groups	Mean ± SD (N/cm)	F	Sig.	T	Df	p-value
1	3.50 ± 0.522	90.829	0.000	4.000	10	0.001 **
5	2.17 ± 1.030				16.306	
2	6.67 ± 0.985	0.741	0.399	8.204	10	0.000 **
6	3.50 ± 0.905				21.843	
3	1.030	2.532	0.126	8.424	10	0.000 **
7	2.50 ± 0.905				21.640	
4	7.83 ± 1.030	6.972	0.015	9.391	10	0.000 **
8	4.33 ± 0.778				20.477	

* p < 0.05; ** p < 0.01.
Table 10: Effect of the insertion angle of miniscrews on the MRT.

		PTV	MIT	MRT
PTV	Pearson Correlation	1	-0.604**	-0.622**
	Sig. (2-tailed)		0.000	0.000
	N	48	48	48
MIT	Pearson Correlation	-0.604**	1	0.936**
	Sig. (2-tailed)	.000		0.000
	N	48	48	48
MRT	Pearson Correlation	-0.622**	0.936**	1
	Sig. (2-tailed)	0.000	0.000	
	N	48	48	48

**: Correlation is significant at p < 0.01.
Table 11: Pearson correlation.

thus to reduce the risk of injury during the insertion of the miniscrew.

The obtained results showed statistically significant differences between the two evaluated insertion angles. These findings were in favor of the 90° angle which provided greater stability in most of the tests: the average values of MIT and MRT were greater and the average values of the Periotest were smaller than in the groups with the 45° angle insertion.

Similar results were reported by Pickard et al. [8] who studied the effect of the miniscrew insertion on its stability. The authors inserted the miniscrews in the lower jaw bone of human bodies with 90° and 45° angles. The extraction and shearing tests were applied to measure the miniscrews stability. They found that the miniscrews inserted with a 90° angle had the highest value of extraction resistance [8]. Also, Wilmes et al. [13] inserted dual-thread miniscrews (1.6 × 8 mm and 2 × 10 mm) according to seven different angles (30°, 40°, 50°, 60°, 70°, 80° and 90°). They measured the insertion torque to determine the primary stability. They found that the insertion angle of the miniscrews had a significant impact on the primary stability. However, the highest value for the MIT was observed with the angles between 60° and 70° [18].

Conclusion

Within the limitations of the present study, we can conclude that modifying the shape of the miniscrew by adding the dual-threads in its cervical portion conferred better primary stability when compared with the normal shape. Also, increasing the length of the miniscrew and inserting the miniscrews perpendicularly with respect to the bone surface increases the primary stability.

Further studies are required to investigate the effect of changing the diameter of miniscrews on the primary stability.

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