Stability of orthodontic miniscrews according to screw design

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Stability of orthodontic miniscrews according to screw design

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감사의 글

부족한 저를 이끌어 주시고 논문의 시작부터 완성되기까지 따뜻한 배려와 가르침으로 이끌어 주신 차정열 지도 교수님께 진심으로 감사와 존경의 말씀을 드리며, 바쁘신 와중에도 귀중한 시간을 내주시어 논문에 관심과 조언을 아끼지 않으신 존경하는 박영철 교수님, 황충주 교수님께도 감사드립니다.

그리고 교정과에 들어와서 3년간의 수련기간 동안 교정학을 배우고 익히는데 많은 가르침을 주신 백형선 교수님, 김경호 교수님, 유형석 교수님, 이기준 교수님, 정주령 교수님, 최윤정 교수님께 감사와 존경의 말씀을 드립니다.

통계 작업에 많은 도움을 주신 연세대학교 원주의과대학 최은희 교수님께 감사 드립니다.

의국 생활 동안 많은 도움을 주시고 큰 힘이 되어주셨던 의국 선배님들과 후배님들, 직원분들께 감사드리며 특히 많은 어려움을 함께한 의국 동기 강다영, 김성진, 손광일, 이다혜, 이희선과 의국 후배 배미주, 최승완 선생, 늘 실험을 함께했던 뭉해도람 선생에게 이 자리를 빌려 감사의 마음을 전해드립니다.

사랑하는 부모님과 누나, 형에게 감사드리며, 늘 곁에서 응원해주는 현우에게 감사의 마음을 전합니다.

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ABSTRACT

Stability of orthodontic miniscrews according to screw design

This study was to evaluate the clinical efficiency of tapered and cylindrical miniscrews by estimating their success rate and long-term stability.

There were 105 tapered and 122 cylindrical self-drilling miniscrews placed into the maxillary and mandibular buccal alveolar areas of 132 patients (43 males, 89 female) who were over 16 years old. The insertion torque (IT) and removal torque (RT) were measured using a torque sensor during implantation and removal of miniscrews and Periotest values (PTV) were recorded. And the miniscrews were checked after implantation to determine success or failure. The results of this study were as follows.

1) The success rates of the tapered and cylindrical miniscrews examined were similar between two types of design.
2) In the buccal side of maxilla, the insertion torque of tapered miniscrews (8.3 Ncm) was significantly higher than that of cylindrical miniscrews (6.3 Ncm) (P <0.05). And the PTVs of the tapered miniscrews were significantly lower than that of cylindrical miniscrews in maxilla (P <0.05).

3) In the maxilla, the miniscrews falling within the low insertion torque range (below 3 Ncm) had a significantly lower success rate than the miniscrews in other groups.

4) The removal torque values showed no significant difference between the tapered and cylindrical miniscrews in the upper and lower buccal areas (P >0.05).

5) The distal area of the first molar had significantly lower success rates than other sites of insertion (P <0.01). But there was no significant difference in success rates according to gender, jaw and side of insertion.

Tapered type miniscrews had higher initial stability compared to cylindrical type miniscrews, whereas the clinical success rates and removal torques were similar between the two designs. The long term stability and success rate can be affected by various factors, such as insertion torque, individual anatomical variation and insertion site.

Key words: Miniscrew, Tapered, Cylindrical, Torque, Periotest value, Stability

Stability of orthodontic miniscrews according to screw design

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Ⅰ. Introduction

Recently, orthodontic miniscrews have shifted the paradigm in orthodontic treatment. Miniscrews have established the concept of absolute anchorage, and orthodontic movements that were difficult in the past have become easier with the aid of miniscrews. However, the possibility for failure following insertion prevents miniscrews from being ideal. Generally, miniscrew failure rates have been reported to be between 10% to 15%(Miyawaki et al., 2003; Motoyoshi et al., 2006a; Tseng et al., 2006) with contributing factors associated with success rate including bone quality, age, interradicular space, location, screw diameter, screw design, and doctor's skill, among others. In particular, the initial stability of miniscrews is assessed as a predictor of success(Motoyoshi et al., 2010). Initial stability also allows for new bone formation at the bone interface(Motoyoshi et al., 2006b) and is essential in preventing

miniscrew mobility within the physiologic limits of bone remodeling because failure can occur if there is mobility during treatment(Motoyoshi et al., 2010) (Ivanoff et al., 1997).

Two factors affect the initial stability of a miniscrew: the screw factor and the host factor. The screw factor is related to the characteristics of the screw design, including diameter and length(Ivanoff et al., 1997). Various screw designs have been introduced to enhance initial stability. The host factor is related to the quantity and quality of the bone where the screw is placed. Cortical bone thickness (CBT) can affect the initial stability of a screw as a main host factor(Cha, Kil, et al., 2010).

Measuring insertion torque(Motoyoshi et al., 2006b) and Periotest value(Cha, Yu, et al., 2010) is efficient ways to evaluate the initial stability of different designs of miniscrews . In order to estimate the miniscrew's stability after insertion, it is necessary to carry out a histomorphometric analysis and measure the removal torque by physical evaluation methods.

As reported in Im's study(J. E. Lim, Lim, et al., 2008), an increase in screw diameter can efficiently reinforce the initial stability of a miniscrew. Since increasing the screw diameter is limited due to root proximity, various tapered miniscrews have been designed to enhance initial stability. Tapered miniscrews increase initial fixation by inducing a controlled

compressive force in the cortical layer without increasing root proximity. This design was originally recommended for immediate loading of prosthodontic implants because it increased the mechanical contact between the dental implant and surrounding bone(Motoyoshi et al., 2006a).

In a previous animal study model, tapered and cylindrical miniscrews were compared to evaluate the miniscrews' stability. There was a significant difference in insertion torque values between the two types of miniscrews. Specifically, there was a significant difference in removal torque between the two types of miniscrews when they were removed after 3 weeks, but there was no statistically significant difference between the two groups when the miniscrews were removed after 12 weeks(Cha, Takano-Yamamoto, et al., 2010). Meanwhile, Suzuki et al(Suzuki et al., 2010) reported that the tapered miniscrews, which had a higher insertion torque, showed less removal torque than the cylindrical miniscrews. These results differed from previous animal studies.

The aims of this investigation were to evaluate the clinical efficiency of tapered and cylindrical miniscrews by estimating their success rate and long-term stability, while also evaluating the relationship between initial and long-term stability.

Ⅱ. Materials and Methods

1. Methods

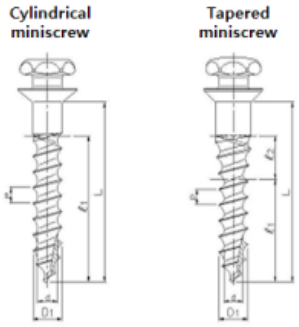
There were 227 tapered (105) and cylindrical (122) self-drilling miniscrews (Biomaterials Korea, Seoul, Korea) placed into the maxillary and mandibular buccal alveolar areas of 132 patients (43 males, 89 female) (Fig. I). The mean age of the patients was 25.3 ± 8.0 years. The inclusion criteria included patients 1) with no general disease, 2) who were over 16 years old and 3) who needed implantation of miniscrews for orthodontic treatment. The miniscrews (Machined surface & Self–drilling) were placed between 2006 and 2011 in the Orthodontic Clinic of Yonsei University Dental Hospital in Seoul, South Korea. The patients were informed of the advantages and disadvantages of this procedure. After collecting informed consent from the patients, the miniscrews were placed.

Two types of miniscrews of various diameters and lengths were used for orthodontic anchor-age: (1) a drill-free and cylindrical type (Biomaterials Korea, Seoul, Korea) with a diameter of 1.5 mm and length of 7 mm; and (2) a drill-free and tapered type (Biomaterials Korea, Seoul, Korea) with a diameter of 1.5 mm and length of 7 mm (Fig. 1). The miniscrews were placed in the following areas: maxillary buccal and mandibular buccal alveolar areas.

Each screw was placed according to the manufacturers' directions. All screws were placed under local infiltration anesthesia and both types of screws were placed using a hand driver directly without predrilling. All screws were placed with normal saline-solution irrigation.

Miniscrews were symmetrically placed in the arches and different screws were placed on the left and right sides. The insertion torque (IT) and removal torque (RT) were measured using a torque sensor (Mark-10, MGT50, CA, USA) during implantation and removal of mini-screws and Periotest® (Siemens, Bensheim, Germany) values (PTV) were recorded as mobility values at implantation.

Almost all of the screws were loaded with 200-250gf and the average placement period of the miniscrews was 15.3 months (Cylindrical: 15.2 months/ Tapered: 15.4 months). The miniscrews were checked after implantation to determine whether miniscrews were success or failure. Success of miniscrews was defined that inserted miniscrews were maintained for over 6 months. Failed miniscrews either had mobility or came out from the alveolar bone. The patient's age, gender, working dates, miniscrew design and insertion sites were recorded.



	Measurement	Type	
		1507C	1507T
D_1	External diameter	1.45	1.45
D_2	External diameter (taper)	-	1.80
d	Internal diameter	1	1
L	Total length	7	7

Fig. 1. Prescription of self-drilling miniscrews tested (in mm)(BMK, Seoul, Korea).

2. Statistical Analysis

All measurements were statistically evaluated using an independent two-sample t-test to determine any difference in the initial and removal torques, PTV and success rates between the cylindrical and tapered miniscrews. A Chi-square analysis was used to analyze the relationship between success rate and miniscrew design, categories of insertion torques and PTV, and the success rates between operators. A *P*-value of <.05 was considered statistically significant. The statistical analyses were performed using SPSS software program (version 18.0, SPSS, Chicago, Ill).

Ⅲ. RESULTS

The success rate of the miniscrews examined in this study was 81.5% (Table 1). And there were no significant difference in success rates among the three operators (P >0.05). Overall success rates were 82.9% and 80.3% for tapered and cylindrical miniscrews, respectively. There was no significant difference in the success rates between the cylindrical and tapered miniscrews (Table 1).

The success rate can be affected by the site of insertion. For instance, the distal area of the first molar had a significantly lower success rate than other sites of insertion (Table 2). Gender, side of insertion and jaw had no statistically significant differences in success rate.

On the buccal side of the maxilla, the insertion torque of tapered miniscrews (8.3 Ncm) was significantly higher than that of cylindrical miniscrews (6.3 Ncm) (P <0.05), and the PTV of the tapered miniscrews (-1.9) was statistically significantly lower than that of cylindrical miniscrews (-0.6) (P <0.05) (Table 3).

Table 1. Success rates of two different miniscrew designs for the maxilla and mandible

	Cylindrical	Tapered	*P*
Maxilla	78.2% (43/55)	80.0% (44/55)	0.815
Mandible	82.1% (55/67)	86.0% (43/50)	0.570
Total	80.3% (98/122)	82.9% (87/105)	0.625

Table 2. Success rates and number of miniscrews according to clinical variables.

Clinical variable	Success rate (%)	Success/total miniscrews (N)	*P* (chi-square or Fisher exact)
Gender			
Male	77	57/74	0.228
Female	83.7	128/153	
Jaw of placement			
Maxilla	79.1	87/110	0.365
Mandible	83.8	98/117	
Side of placement			
Right	78.5	84/107	0.273
Left	84.2	101/120	
Site of placement			
Incisor to PM1	81.8	18/22	0.011*
PM1 to M1	85	147/173	
M1 to M2	62.5	20/32	

PM1, 1st premolar; M1, 1st molar; M2, 2nd molar; * significance at the 0.05 level

Table 3. Peak insertion and removal torque values (in Ncm) and Periotest values (PTV)

	Insertion						Removal					
	Torque value			Periotest value			Torque value			Periotest value		
	Cylindrical	Tapered	*P*	Cylindrical	Tapered	*P*	Cylindrical	Tapered	*P*	Cylindrical	Tapered	*P*
Maxilla	6.3±2.8	8.3±3.7	0.010*	- 0.6±5.0	- 1.9±3.4	0.034*	3.9±1.6	3.9±1.8	0.382	5.8±6.4	3.8±6.1	0.916
Mandible	7.8±3.5	9.2±4.0	0.560	1.7±4.6	-0.6±4.1	0.206	3.9±2.3	4.1±2.1	0.657	7.8±6.9	5.2±6.4	0.512

* significance at the 0.05 level

On the buccal side of the mandible, the insertion torque between the tapered miniscrews (9.2 Ncm) was higher than cylindrical miniscrews (7.8 Ncm), but this was not statistically significant (P <0.05). Furthermore, the PTVs of the tapered (-0.6) and cylindrical miniscrews (1.7) were not significantly different (P <0.05) (Table 3).

Furthermore, on the buccal side of the maxilla, the insertion torque values of the success group (7.4 Ncm) were similar to that of the failure group (7.1 Ncm) (Table 4). There was no significant difference in insertion torque values between the success group (8.3 Ncm) and failure group (9.2 Ncm) on the buccal side of the mandible as well. The PTVs showed no significant difference between the success and failure groups in the upper and lower buccal areas (Table 4).

Table 4. Mean and range of insertion torques and Periotest values for success and failure group

Location		Insertion Torque (Ncm)			Periotest value (PTV)		
		N	Mean±SD	*P*	N	Mean±SD	*P*
Maxilla	Success	82	7.4±3.34	0.547	77	-1.5±4.14	0.677
	Failure	23	7.1±3.69		20	-0.2±4.69	
Mandible	Success	94	8.3±3.81	0.613	92	0.6±4.53	0.755
	Failure	18	9.2±3.56		17	1.2±4.60	

Table 5. Relationship between initial torques values by category and success rate

Torque Category (Ncm)	Total Success Rate (%)	Mx. Success Rate (%)	Mn. Success Rate (%)
Below 3	61.5 (8/13)	28.6 (2/7)	100 (6/6)
3~11	83.9 (130/155)	82.9 (68/82)	84.9 (62/73)
Above 11	77.6 (38/49)	75.0 (12/16)	78.8 (26/33)
P-value	0.109	0.004*	0.397

* significance at the 0.05 level

Table 6. Relationship between Periotest values by category and success rate

PTV Category	Total Success Rate (%)	Mx. Success Rate (%)	Mn. Success Rate (%)
Below-5	86.4 (19/22)	92.3 (12/13)	77.8 (7/9)
-5~5	80.5 (124/154)	76.0 (57/75)	84.8 (67/79)
Above 5	86.7 (26/30)	88.9 (8/9)	85.7 (18/21)
P-value	0.620	0.309	0.845

* significance at the 0.05 level

The removal torques (Mx. Cylindrical: 3.9 Ncm, Tapered: 3.9 Ncm, Mn. Cylindrical: 3.9 Ncm, Tapered: 4.1 Ncm) and PTV values (Mx. Cylindrical: 5.8, Tapered: 3.8, Mn. Cylindrical: 7.8, Tapered: 5.2) showed no significant difference between the tapered and cylindrical miniscrews in the upper and lower buccal areas (Table 3). And no correlation was found between the insertion and removal torques in both the maxilla and mandible ($P > 0.05$).

The results were divided into three categories based on insertion torque and PTV (Table 5,6). The range of three categories was one standard deviation below and above the mean values. Miniscrew with low insertion torque values (below 3 Ncm) had a significantly lower success rate than those in other categories in maxilla. However, PTV categories showed similar success rates.

Ⅳ. DISCUSSION

In this study, the tapered miniscrews had higher average insertion torque values (Mx. Tapered : 8.3 Ncm, Cylindrical : 6.3 Ncm, Mn. Tapered : 9.7 Ncm, Cylindrical : 7.8 Ncm) and these values were significantly higher for the maxilla. These results are in accordance with those of synthetic bone or in vitro studies, which reported that tapered miniscrews showed higher placement torque values than cylindrical miniscrews(S. A. Lim, Cha, et al., 2008; Pithon et al., 2011). However, the measured torque values differed from existing studies because of differences in bone quality and characteristics (Cha, Kil, et al., 2010).

Due to the fact that cortical bone in the mandibular buccal area is thicker than in the maxillary buccal area (Farnsworth et al., 2011; Hu et al., 2009), insertion torque values were expected to be higher in the mandible (Cha, Kil, et al., 2010; Homolka P, 2002). In this study, miniscrews placed in the mandible had higher insertion torque values than in the maxilla, but there was no significant difference in these values. Furthermore, in the mandible, insertion torque values for the two designs differed less when compared to the maxilla. It is possible that our study may have been affected by the difference in placement depths of the miniscrews or any deformation beyond physiological limits that were perceived as torque limits.

Placement depth of a miniscrew can be affected by the surrounding soft tissues (Meredith, 1998). Hu et al(Hu et al., 2009) reported that the attached gingiva in the maxillary premolar and molar areas to be 2.4 mm and 3.5 mm, respectively. The attached gingiva in the mandibular premolar area was 1.4 mm while the mandibular molar area was 2.3 mm. The zone of attached gingiva in the mandibular premolar area was narrow, making it difficult to ensure placement within the zone. In particular, due to the increasing diameter of tapered miniscrews toward the head, insertion torque can be lowered if the threads are not completely buried.

Suzuki et al(Suzuki and Suzuki, 2011) clinically evaluated the design and stability of miniscrews and reported that tapered miniscrews had higher insertion torque values than cylindrical miniscrews. While this report corresponds to the results of our study, the measured values of insertion torque (Mx. Self-drilling tapered: 12.1 Ncm, Predrilling Cylindrical: 7.2 Ncm, Mn. Self-drilling tapered: 15.7 Ncm, Predrilling Cylindrical: 12.1 Ncm) were differ from values measured in this study. However, objective comparison between the two studies is difficult because different insertion techniques were used for each screw type in Suzuki's study.

Existing studies regarding insertion torque report that stability is low when IT values are too low or high. Motoyoshi et al(Motoyoshi et al., 2006b) reported that miniscrews with IT values

in the range of 5 to 10 Ncm had greater stability for a variety of reasons. Firstly, greater insertion torque of a miniscrew can generate excessive stress surrounding the dental implant threads. If this stress reaches a high level, necrosis and local ischemia of the bone at the implant-tissue interface can result. Secondly, very high insertion torque can also generate high levels of stress, resulting in degeneration of the bone at the implant-tissue interface, and as a result, bone regeneration surrounding the implant thread may be aggravated (Meredith, 1998). In this study, there was a statistically lower success rate in the low category group (IT: below 3 Ncm) in the maxilla (Table. 4). And in the middle category group (IT: 3-11 Ncm), we found a higher success rate than other categories in the maxilla, but there was no significant difference. So, we concluded that 1.5mm diameter miniscrews do not provoke excessive insertion torque, which in turn leads to high levels of stress in the buccal alveolar area. Furthermore, the success rate in this study affected lower insertion torque more than higher insertion torque.

In this study, removal torque values in the maxilla were 3.9 Ncm and 3.9 Ncm for cylindrical and tapered miniscrews, respectively. In the mandible, these values were measured at 3.9 Ncm for cylindrical miniscrews and 4.1 Ncm for tapered miniscrews. The respective

types of miniscrews exhibited similar removal torque values while the maxilla and mandible also demonstrated similar average values for removal torque. This suggests that the removal torque has no correlation with insertion torque.

Pithon et al(Pithon et al., 2011) used mini-pigs in their study and reported that the tapered miniscrews had greater removal torque than the cylindrical type of miniscrews. However, the study by Pithon et al differs from our study because the screws were placed in the ribs of the mini-pigs, which does not accurately reflect a clinical environment. Conversely, Suzuki et al (Suzuki and Suzuki, 2011) reported that the cylindrical miniscrew had greater removal torque than the tapered miniscrew, and also reported that the removal torque values were greater than insertion torque values in the tapered and cylindrical miniscrews. These results are contrary to the findings in this study. Generally, stress resulting from bone deformation generated during insertion decreases as time passes. Removal torque continues to decrease until complete osseointegration occurs. In fact, Motoyoshi et al(Motoyoshi et al., 2010) (Insertion Torque: Mx. 7.7 Ncm, Mn. 8.4 Ncm, Removal Torque: Mx. 4.4 Ncm, Mn. 4.1 Ncm) presented results showing that removal torque was lower in comparison to insertion torque, which corresponds with the results of our study.

In an animal experiment using beagle dogs, tapered and cylindrical miniscrews were implanted then removed after 3 weeks and 12 weeks. The removal torque of the tapered miniscrew was significantly higher than that of the cylindrical in the 3 weeks group, while removal torque of both types had similar values for the 12 weeks group (4.2 and 3 Ncm for the tapered and cylindrical miniscrew, respectively(Cha, Takano-Yamamoto, et al., 2010). Considering the average placement period of 15.3 months in this study, it was noted that removal torque values became similar between the two types when miniscrews placed in the mouth were maintained over a long period of time. However, we must also take into consideration the fact that any increase of removal torque by osseointegration could not be confirmed.

In this study, PTVs of the tapered miniscrews (upper, -1.9; lower, -0.6) were lower than that of the cylindrical miniscrews (upper, -0.6; lower, 1.7), with a significant difference in the maxilla ($p<0.05$). The PTVs have been used to evaluate mini-implant stability, and PTVs at insertion have been reported to be significantly correlated with insertion torque ($P<0.05$), especially in the mandible (Cha, Yu, et al., 2010). A previous animal study reported that PTVs were significantly different between tapered and cylindrical miniscrews(Cha, Kil, et al., 2010).

In this study, PTV of tapered miniscrews was lower than that of cylindrical miniscrews in the maxilla and showed significant differences only when compared to the mandible.

Furthermore, miniscrews showed higher IT values in the mandible than the maxilla, with mobility values also being higher in the mandible. Therefore, further study is needed to evaluate any absolute correlation between insertion torque at initial placement and PTVs.

In this study, we found a miniscrew success rate of 81.5%, which is relatively low when compared to previous studies. For instance, success rates of 83.9% (1.5mm diameter) and 85% (2.3-mm diameter) were reported by Miyawaki et al.(Miyawaki et al., 2003) Meanwhile, Meredith et al(Meredith, 1998) reported a miniscrew success rate of 83.8%, while Suzuki et al(Suzuki and Suzuki, 2011) reported over 90% success rate. Our study may have produced a success rate that differs from other reports for a few different reasons. Firstly, some studies incorporated the use of a miniscrew guide during implantation, which can affect the success rate. However, it is not easy to use a miniscrew guide on all patients in a real clinical environment. Secondly, operator proficiency in miniscrew placement can influence success rates.

Although the failure group did not show a significant difference in insertion torque values, higher values were detected in the mandible, possibly due to root contact (Kuroda et al., 2007).

After miniscrew placement, periapical radiographs were taken for almost all cases and most of the failed screws were very close to roots radiographically. Miniscrew placement and operator efficiency were a few of the limitations in this study but every effort was made to ensure objectivity in this prospective and randomized clinical trial.

Future studies which further examining miniscrews and the relationship between insertion torque and mobility will help to give us a greater understanding of how to maximize and maintain initial stability.

Ⅴ. CONCLUSION

To evaluate the clinical efficiency of tapered and cylindrical miniscrews, 105 tapered and 122 cylindrical self-drilling miniscrews placed into the maxillary and mandibular buccal alveolar areas of 132 patients (43 males, 89 female) who were over 16 years old.

The insertion torque of tapered miniscrews was significantly higher than that of cylindrical miniscrews in the maxilla. And the insertion PTV of the tapered miniscrews was statistically lower than that of cylindrical miniscrews in the maxilla. Although removal torque and PTV of the two types of miniscrews were similar in the maxilla and mandible. Tapered miniscrews affected the initial stability, but the long term stability and success rate of tapered and cylindrical miniscrews were similar. And the distal area of the first molar had significantly lower success rates than other sites of insertion ($P < 0.01$). But there was no significant difference in success rates according to gender, jaw and side of insertion. Consequently, long term stability and success rate can be affected by various factors such as insertion torque, individual anatomical variation and insertion site.

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국 문 요 약

교정용 미니스크류의 디자인에 따른 임상적 안정성

<지도교수 : 차정열>

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유성훈

미니스크류의 초기 안정성 개선을 위해 쉽게 조절할 수 있는 요소가 미니스크류의 디자인이지만, 장기적인 안정성 비교가 부족한 실정이다. 본 연구는 원추형과 원통형 미니스크류의 성공률과 안정성을 비교하여 원추형 미니스크류의 임상적 효용성에 대하여 평가하고자 하였다.

105개의 원추형과 122개의 원통형 self-drilling 미니스크류를 16세 이상의 건강한 성인 132명을 대상으로 상악과 하악의 협측 치조골에 식립하였다. 토오크 센서와 페리오테스트® 장치를 이용하여 식립 토오크와 동요도를 측정하였으며, 미니스크류의 제거 시 토오크와 동요도, 성공률을 측정하여 다음과 같은 결과를 얻었다.

1) 원추형과 원통형의 미니스크류는 유사한 성공률을 보였다.
2) 상악에서 원추형의 미니스크류(8.3 Ncm)가 원통형(6.3 Ncm)에 비하여 통계적으로 유의성 있게 높은 식립 토오크 측정값을 보였으며(P <0.05), 동요도는 상악에서 원추형 미니스크류가 원통형 미니스크류보다 유의성 있게 낮은 값을 보였다 (P<0.05).

3) 식립 토오크와 동요도를 세 범주(높음, 중간, 낮음)로 나누어 성공률과의 연관성에 대하여 평가한 경우, 상악에서 식립 토오크가 낮은 군 (3 Ncm 이하)에서 유의성 있게 낮은 성공률을 보였다.

4) 제거 토오크는 상악과 하악 모두에서 원추형과 원통형 미니스크류 간에 유의성 있는 차이를 보이지 않았다 (P>0.05).

5) 식립 위치에 따른 성공률 평가 시, 제1대구치 후방에 식립한 군에서 성공률이 유의성 있게 낮은 값을 보였다 (P<0.01).

원추형 미니스크류는 원통형 미니스크류에 비하여 비교적 높은 식립 토오크를 보이지만 성공률과 제거 토오크의 값은 유사한 양상을 보인다. 이를 바탕으로, 장기적인 안정성과 성공률이 미니스크류의 디자인 요소 이외에 식립 토오크, 환자 고유의 해부학적 제약 및 식립 위치 등의 다른 요소들에 의해 영향을 받는 다고 평가할 수 있다.

핵심 되는 말: 원추형 미니스크류, 원통형 미니스크류, 토오크, 동요도, 안정성