ORIGINAL ARTICLE https://doi.org/10.4047/jkap.2022.60.2.143

두 가지 임플란트 드릴 조합에 따른 온도 변화 및 효율 비교

Temperature change and performance of bur efficiency for two different drill combinations

황보흥[1]·박재영[1]·이상윤[1]·손큰바다[2]*·이규복[2,3]*
Heung Hwang-Bo[1], Jae-Young Park[1], Sang-Youn Lee[1], Keunbada Son[2]*, Kyu-Bok Lee[2,3]*

[1]CSM 임플란트, [2]경북대학교 첨단치과의료기기개발연구소, [3]경북대학교 치과대학 치과보철학교실
[1]Research Institute, CSM Implant, Daegu, Republic of Korea
[2]Advanced Dental Device Development Institute (A3DI), Kyungpook National University, Daegu, Republic of Korea
[3]Department of Prosthodontics, School of Dentistry, Kyungpook National University, Daegu, Republic of Korea

ORCID iDs
Heung Hwang-Bo
https://orcid.org/0000-0002-0844-8956
Jae-Young Park
https://orcid.org/0000-0001-9158-3800
Sang-Youn Lee
https://orcid.org/0000-0001-8899-0907
Keunbada Son
https://orcid.org/0000-0002-3177-8005
Kyu-Bok Lee
https://orcid.org/0000-0002-1838-7229

Corresponding Author
Keunbada Son*, Kyu-Bok Lee**
*Advanced Dental Device Development Institute (A3DI),
**Department of Prosthodontics, School of Dentistry, Kyungpook National University, 2177 Dalgubuldaero, Jung-gu, Daegu 41940, Republic of Korea
*+82 (0)53 660 6925
sonkeunbada@gmail.com
**+82 (0)53 600 7674
kblee@knu.ac.kr

Article history Received January 4, 2022 / Last Revision March 3, 2022 / Accepted March 10, 2022

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No.2022R1C1C2007040).
This project was supported by the 2021 regional and industry-tailored job creation program, which was carried out from April to October 2021.
This research was funded by Daegu Techno Park's research and development activities.

Purpose. The purpose of this study was to evaluate the performance efficiency of two different drill combinations according to the heat generated and drilling time. **Materials and methods.** In this study, cow ribs were used as research materials. To test the specimen, cow bones were rid of fascia and muscles, and a temperature sensor was mounted around the drilling area. The experimental group was divided into a group using a guide drill and a group using a Lindmann drill according to the drill used before the initial drilling. The drilling sequence of the guide drilling group is as follows; guide drill (ø 2.25), initial drill (ø 2.25), twist drill (ø 2.80), and twist drill (ø 3.20). The drilling sequence of the Lindmann drilling group is as follows; Lindmann drill (ø 2.10), initial drill (ø 2.25), twist drill (ø 2.80), and twist drill (ø 3.20). The temperature was measured after drilling. For statistical analysis, the difference between the groups was analyzed using the Mann-Whitney U test and the Friedman test was used (α = .05). **Results.** The average performance efficiency for each specimen of guide drilling group ranged from 0.3861 to 1.1385 mm^3/s and that of Lindmann drilling group ranged from 0.1700 to 0.4199 mm^3/s. The two drill combinations contained a guide drill and Lindmann drill as their first drills. The combination using the guide drill demonstrated excellent performance efficiency when calculated using the drilling time (P < .001). **Conclusion.** Since the guide drill group showed better performance efficiency than the Lindmann drill group, the use of the guide drill was more suitable for the primary drilling process. (J Korean Acad Prosthodont 2022;60:143-51)

Keywords

Dental implants; Efficiency; Implant handpiece; Temperature change

Introduction

For more than 30 years, dental implants have been commonly used to safely replace a part of or the entire teeth of patients.[1] Several types of implants are available, from partially replacing a tooth to replacing the entire denture; treatment methods and tools have also improved. Topics related to dental implants are important issues in dentistry and veterinary science. Dental implantation is performed through various methods and tools.[2]

Despite improvements in dental tools, implants may cause complications, one of which is the excessive rise in temperature during drilling, which damages the bone and causes necrosis. The threshold for bone necrosis is between 47°C and 55°C, and the procedure of drilling is often at a risk of overheating.[3]

In dental clinics, various implant drill combinations are used depending on the situation. For computer-guided implant surgery, initial drilling should be used as a guide drill. If the bone is not flat, a Lindmann drill may be used in the initial drilling process. However, studies on these various drill combinations are still lacking.

This study aimed to evaluate two combinations of drilling systems based on their efficiency in shortening the drilling time and ensuring minimal temperature increase under critical temperature levels that cause bone necrosis.

Materials and methods

The experiment were conducted using Korean cow ribs of similar sizes. The muscles and fascia of the ribs were removed, the bones were cut into sizes of 4 cm, and the bottom surface was selected and processed flat. Then, the surface to be tested was polished using sandpaper of #400, #800, #1000, and #1200.

The final diameter of the drilling site was ø 3.3. Four holes with a diameter of ø 2.0 and a depth of 5 mm were drilled at an angle of 90 degree, each 3 mm from the outer diameter of the drilling site. The experiment was performed after the temperature sensor was inserted into the processed holes.

Figure 1 show the shapes of the following drill combinations used in the experiment: (1) Guide drilling group: guide drill (ø 2.25, CSM Implant, Daegu, Republic of Korea), initial drill (ø 2.25), twist drill (ø 2.80), and twist drill (ø 3.20); (2) Lindmann drilling group: Lindmann drill (ø 2.10), initial drill (ø 2.25), twist drill (ø 2.80), and twist drill (ø 3.20).

In this study, Implant handpiece system (SIP20 and CRB46LN; Saeshin, Daegu, Republic of Korea) was used, and the temperature was measured using the midi LOGGER GL240 model (Graphtec Co., Ltd., Irvine, CA, USA). An experimental custom-made device was used to hold the implant handpiece (Fig. 2). For holding repeatability

Fig. 1. Drill combination used in the experiment. (A) Guide drilling group, (B) Lindmann drilling group.

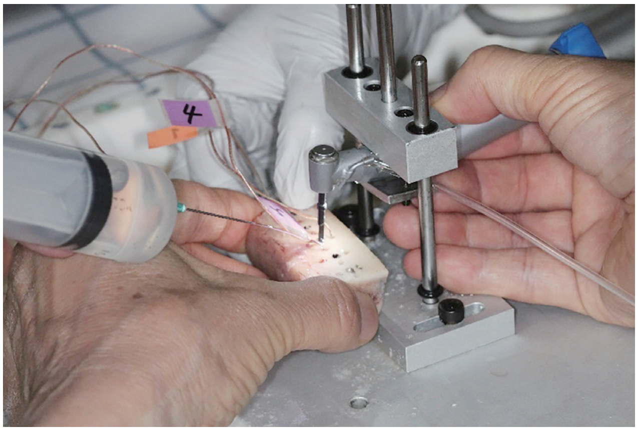

Fig. 2. Experiment preparation with custom-made device.

of the specimen and implant handpiece, holding was carried out using a right-angle gauge so that the drill of the implant handpiece and specimen were vertical, and the end of the drill was positioned at the end of the specimen (Fig. 2).

The materials were set on a stable workbench, and drilling procedures were performed using optimal force by an experienced researcher, who received repeated training from skilled professors. During drilling, a rotational speed of 1500 rpm was used and saline solution at room temperature was injected. In guide drilling group, a small groove was made with a guide drill; drilling was performed in the following order: initial drill, twist drill (ø 2.8), and twist drill (ø 3.2). The temperature after each drilling was measured and recorded using a thermometer. In Lindmann drilling group, a Lindmann drill was used first, and subsequent drilling was conducted in the same order as guide drilling group. The experiments were conducted in the same enclosed space under the same temperature and humidity conditions.

To calculate the performance efficiency during the drilling process for each combination, the volume of the last drill and Lindmann drill was modeled using the NX UG program (Siemens PLM Software, Torrance, CA, USA) to derive the volume at the time of 11-mm drilling, and the performance efficiency was calculated by dividing the result value by time (second). The calculated value was the volume cut per second (mm^3/s), and each value was compared and analyzed.

All data were analyzed using a statistical software (SPSS ver 25.0; IBM, Chicago, IL, USA) (α = .05). First, the normal distribution of the data was investigated through the Shapiro-Wilk test, and the difference between the groups was verified using the Mann–Whitney U test because the normal distribution was not achieved. The Friedman test was used to confirm the change.

Results

Table 1 shows the temperature change at each of the four temperature measurement points by drilling 4 - 6 holes for each specimen during drilling using guide drilling group and the time required for drilling (Fig. 3). With the guide drill, the entire hole was not drilled, and only the sharp blade was used to drill to a depth of 2 mm. For other drills, drilling was performed to a depth of 11 mm.

The average temperature change for each drilling showed a temperature increase from 2.6°C to 5.8°C, and the drilling time for each drilling ranged from 56.84 to 245.99 s (P < .001). The average temperature change for each specimen ranged from 2.62°C to 5.88°C, and the average drilling time for each specimen ranged from 71.21 to 208.00 s.

Table 2 shows the temperature and drilling time measured at four points by drilling 4 - 6 holes for each specimen using Lindmann drilling group (Fig. 4). In Lindmann drilling group, drilling was performed to a depth of 11 mm using the Lindmann drill first, and subsequent drilling was made to a depth of 11 mm using the other three drills.

For each specimen, the temperature rises were ranged from 1.61°C to 3.22°C, and the drilling time for each drilling point was 105.87 - 480.91 seconds (P < 0.001). The average time of the Lindmann drill for each specimen was 122.53 - 299.03 seconds.

Table 1. Average temperature and time of the first drill combination

Specimen no.	No.	Drilling time (second)	Average temperature change (°C)	Average temperature change (°C)	Average drilling time (second)
1	1	94.44	5.50	2.62	71.21
	2	73.07	2.42		
	3	60.51	1.97		
	4	56.84	0.60		
2	1	115.51	5.72	3.49	202.56
	2	169.85	4.87		
	3	175.30	2.52		
	4	241.88	2.60		
	5	176.55	2.15		
	6	133.74	3.10		
3	1	187.60	4.90	5.88	208.18
	2	228.64	5.45		
	3	245.99	5.85		
	4	226.50	6.20		
	5	152.19	7.02		
4	1	181.12	4.82	3.08	146.77
	2	177.51	2.62		
	3	102.35	1.95		
	4	142.80	2.37		
	5	130.10	3.62		

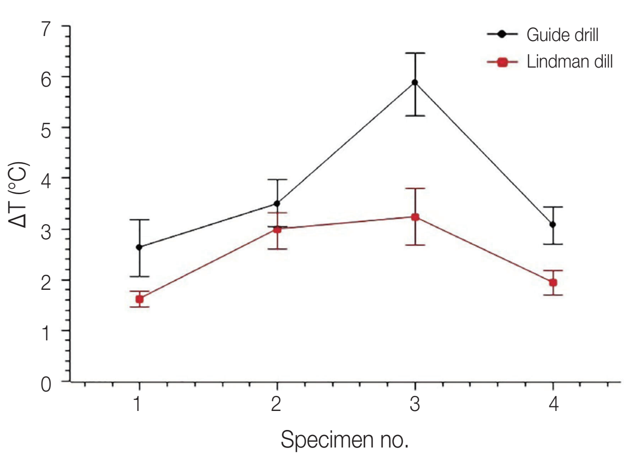

Fig. 3. Comparison of temperature changes during drilling for each drill combination while drilling a hole in the specimen.

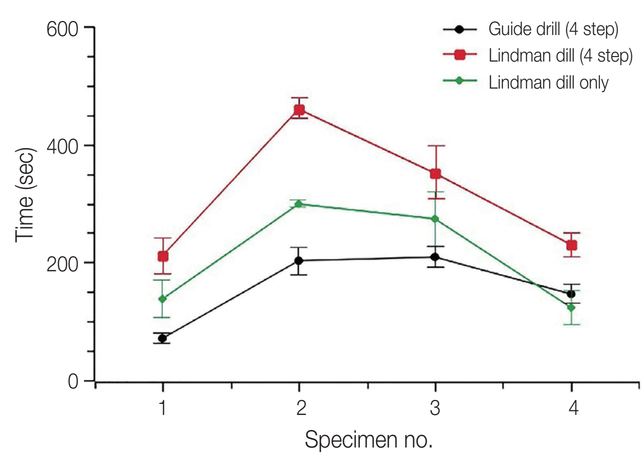

Fig. 4. Comparison of drilling time in the specimen for each drill combination.

Table 3 shows the volume of cuts per second for each combination along with the performance efficiency for each drilling point and the average drilling time and performance efficiency for each specimen (Fig. 5, Fig. 6). The total drilled volume was 79.9882 mm^3 using the NX UG program, and the cut volume was calculated by dividing the total volume by each time. The average performance efficiency for each specimen of guide drilling

Table 2. Average temperature and time of the second drill combination

Specimen no.	No.	Drilling time (s)	Average temperature change (°C)	Average time of the Lindmann drill (s)	Average drilling time (s)
1	1	228.54	1.61	138.24	211.62
	2	301.65			
	3	248.62			
	4	173.46			
	5	105.87			
2	1	477.69	2.99	299.03	459.41
	2	480.91			
	3	475.86			
	4	403.20			
3	1	406.27	3.22	273.72	352.23
	2	424.52			
	3	238.58			
	4	339.57			
4	1	253.74	1.95	122.53	229.34
	2	299.61			
	3	170.45			
	4	226.59			
	5	187.68			
	6	237.99			

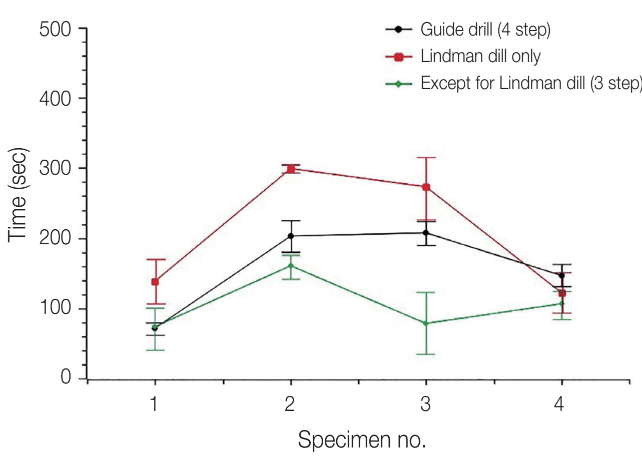

Fig. 5. Comparison of the Lindmann drill time and drilling time, excluding the Lindmann drill and drilling time of the first drill combination.

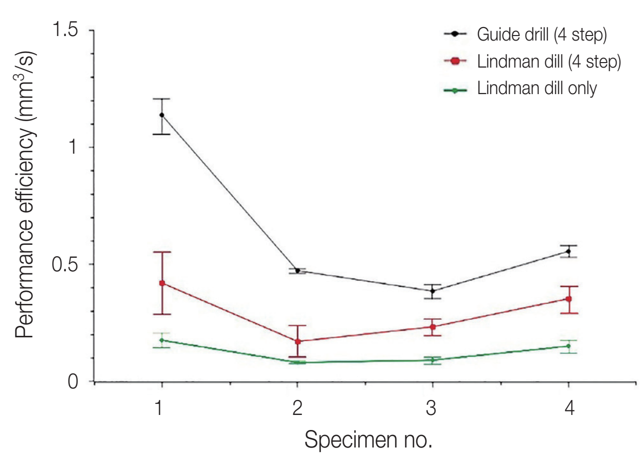

Fig. 6. Performance efficiency values for each drill combination and Lindmann drill.

group ranged from 0.3861 to 1.1385 mm^3/s and that of Lindmann drilling group ranged from 0.1700 to 0.4199 mm^3/s.

Table 4 shows the performance efficiency and the volume cut per second of the Lindmann drill (Fig. 5, Fig. 6). The calculated drilling volume of the Lindmann drill using a modeling program was 24.4461 mm^3. The final performance efficiency ranged from 0.0817 to 0.1768 mm^3/s.

Table 3. Performance efficiency of the first and second drill combinations

Combination of drills used	Specimen no.	No.	Drilling time (second)	Performance efficiency by drilling point (mm³/s)	Average drilling time (second)	Average performance efficiency by specimen (mm³/s)
Guide drill	1	1	94.44	0.8257	71.21	1.1385
		2	73.07	1.0673		
		3	60.51	1.2888		
		4	56.84	1.3720		
	2	1	115.51	0.6751	202.56	0.4720
		2	169.85	0.4591		
		3	175.30	0.4448		
		4	241.88	0.2281		
		5	176.55	0.4417		
		6	133.74	0.5831		
	3	1	187.60	0.4157	208.18	0.3861
		2	228.64	0.3410		
		3	245.99	0.3170		
		4	226.50	0.3443		
		5	152.19	0.5124		
	4	1	181.12	0.4305	146.77	0.5554
		2	177.51	0.4393		
		3	102.35	0.7619		
		4	142.80	0.5461		
		5	130.10	0.5994		
Lindmann drill	1	1	228.54	0.3412	211.62	0.4199
		2	301.65	0.2585		
		3	248.62	0.3136		
		4	173.46	0.4496		
		5	105.87	0.7366		
	2	1	477.69	0.1632	459.41	0.1700
		2	480.91	0.1621		
		3	475.86	0.1638		
		4	403.20	0.1910		
	3	1	406.27	0.1919	352.23	0.2330
		2	424.52	0.1837		
		3	238.58	0.3268		
		4	339.57	0.2296		
	4	1	253.74	0.3073	229.34	0.3521
		2	299.61	0.2602		
		3	170.45	0.4575		
		4	226.59	0.3441		
		5	187.68	0.4155		
		6	237.99	0.3276		

Table 4. Performance efficiency of the Lindmann drill

Specimen no.	No.	Drilling time of the Lindmann drill (second)	Performance efficiency of the Lindmann drill (mm^3/s)	Average drilling time of the Lindmann drill (second)	Average performance efficiency by specimen (mm^3/s)
1	1	120.00	0.2037	138.24	0.1768
	2	239.09	0.1022		
	3	167.82	0.1456		
	4	111.68	0.2188		
	5	52.64	0.4644		
2	1	314.70	0.0776	299.03	0.0817
	2	308.11	0.0793		
	3	302.23	0.0808		
	4	271.08	0.0901		
3	1	346.68	0.0705	273.72	0.0893
	2	326.99	0.0747		
	3	155.81	0.1568		
	4	265.40	0.0921		
4	1	163.20	0.1497	122.53	0.1497
	2	238.42	0.1025		
	3	71.28	0.3429		
	4	99.76	0.2450		
	5	59.29	0.4123		
	6	103.25	0.2367		

Discussion

This study aimed to evaluate the importance of the first drill (guide drill and Lindmann drill) in two drill combinations. For computer-guided implant surgery, initial drilling should be used as a guide drill. If the bone is not flat, a Lindmann drill may be used in the initial drilling process. However, studies on these various drill combinations are still lacking.

Various factors affect heat generation during drilling, including the thickness of the cortical plate, rotational speed, drill diameter, and penetration depth.[4-9] Moreover, a study reported that exposure to high temperatures causes bone necrosis and that temperatures above 47°C negatively affect osseointegration.[3] In other implant systems, the optimal rotation speed to prevent osseointegration and bone overheating ranges from 1000 to 1500 rpm.[4] In the present study, a rotation speed of 1500 rpm was used, and this speed generated the most heat during the test.

In this study, we evaluated the performance efficiency of two drill combinations based on the heat generated and drilling time. Excessive temperature rise during drilling may adversely affect bone transplantation and tissues at the drilling site.

The amount of energy emitted is influenced by various factors, such as the bone type, drill type, and drilling method; thus, the variables in this study were the drill types. With a thermometer sensor attached to a depth of 5 mm in the drilling hole, the heat generated during drilling was measured, and the change in heat generated and drilling time was observed. The distance between the measurement point and drilled surface was 1 mm.

Temperature is affected by various factors, such as indoor temperature, humidity, ventilation conditions, and external heat sources.[10-12] Therefore, this study was performed under the same environmental conditions.

As shown in Figure 3, the temperature change in guide drilling group was higher than that in Lindmann drilling group. Figure 4 shows the increase in the drilling time of guide drilling group compared with Lindmann drilling group; the time taken by the Lindmann drill in Lindmann drilling group was also measured. Figure 5 shows the time excluding the use of the first drill in the two drill combinations. Guide drilling group took a shorter drill time than Lindmann drilling group. With Lindmann drilling group, the drilling time of the Lindmann drill accounted for 53.40% - 77.70% of the total drilling time.

Upon comparison, the performance efficiency (Fig. 6) of guide drilling group was observed to be higher than that of Lindmann drilling group. In the drilling process performed in the present study, it may be difficult to standardize the bone quality of the bovine ribs, and it is necessary to standardize the repeated drilling. Additional studies to standardize drilling should be performed.

Conclusion

In the implant drilling process, the type of initial drill affected the performance efficiency. Since the group using the guide drill showed better performance efficiency than the group using the Lindmann drill, the use of the guide drill was more suitable for the primary drilling process.

References

1. Naito M, Lung K, Linke B. Retrospective analysis of the survival of dental implants placed by dental students: a 10-year chart review. J Can Dent Assoc 2020;86:k11.
2. Kirstein K, Dobrzyński M, Kosior P, Chrószcz A, Dudek K, Fita K, Parulska O, Rybak Z, Skalec A, Szklarz M, Janeczek M. Infrared thermographic assessment of cooling effectiveness in selected dental implant systems. Biomed Res Int 2016;2016:1879468.
3. Kniha K, Heussen N, Weber E, Möhlhenrich SC, Hölzle F, Modabber A. Temperature threshold values of bone necrosis for thermo-explantation of dental implants-a systematic review on preclinical in vivo research. Materials (Basel) 2020;13:3461.
4. Kim SJ, Yoo J, Kim YS, Shin SW. Temperature change in pig rib bone during implant site preparation by low-speed drilling. J Appl Oral Sci 2010;18:522-7.
5. Chacon GE, Bower DL, Larsen PE, McGlumphy EA, Beck FM. Heat production by 3 implant drill systems after repeated drilling and sterilization. J Oral Maxillofac Surg 2006;64:265-9.
6. Alves SF, Wassall T. In vitro evaluation of osteoblastic cell adhesion on machined osseointegrated implants. Braz Oral Res 2009;23:131-6.
7. Misir AF, Sumer M, Yenisey M, Ergioglu E. Effect of surgical drill guide on heat generated from implant drilling. J Oral Maxillofac Surg 2009;67:2663-8.
8. Sharawy M, Misch CE, Weller N, Tehemar S. Heat generation during implant drilling: the significance of motor speed. J Oral Maxillofac Surg 2002;60:1160-9.
9. Cordioli G, Majzoub Z. Heat generation during implant site preparation: an in vitro study. Int J Oral Maxillofac Implants 1997;12:186-93.
10. Lamazza L, Lollobrigida M, Vozza I, Palmieri L, Stacchi C, Lombardi T, De Biase A. Piezoelectric implant site preparation: influence of handpiece movements on temperature elevation. Materials (Basel) 2020;13:4072.
11. Scarano A, Lorusso F, Noumbissi S. Infrared thermographic evaluation of temperature modifications induced during implant site preparation with steel vs. zirconia implant drill. J Clin Med 2020;9:148.
12. Katic Z, Jukic T, Stubljar D. Effects of osteotomy lengths on the temperature rise of the crestal bone during implant site preparation. Implant Dent 2018;27:213-20.

두 가지 임플란트 드릴 조합에 따른 온도 변화 및 효율 비교

황보흥[1] · 박재영[1] · 이상윤[1] · 손큰바다[2]* · 이규복[2,3]*
[1]CSM 임플란트, [2]경북대학교 첨단치과의료기기개발연구소, [3]경북대학교 치과대학 치과보철학교실

목적: 본 연구의 목적은 두 가지 다른 임플란트 드릴 조합을 사용하여 열 발생과 드릴링 시간에 따른 성능 효율성을 평가하는 것이다. **재료 및 방법:** 본 연구에서는 소갈비뼈를 연구재료로 사용하였다. 표본을 시험하기 위해 소의 뼈에서 근막 및 근육을 제거하고 드릴링 영역 주위에 온도 센서를 장착했고, 드릴링 후 온도 및 시간을 측정하였다. 실험군은 이니셜 드릴 전에 사용하는 드릴에 따라 가이드 드릴 사용 그룹과 린드만 드릴 사용 그룹으로 나누었다. 가이드 드릴 사용 그룹의 드릴 사용 순서는 다음과 같다; guide drill (ø 2.25), initial drill (ø 2.25), twist drill (ø 2.80), 그리고 twist drill (ø 3.20). 린드만 드릴 사용 그룹의 드릴 사용 순서는 다음과 같다; Lindmann drill (ø 2.10), initial drill (ø 2.25), twist drill (ø 2.80), 그리고 twist drill (ø 3.20). 통계적 분석은 Mann-Whitney U test 및 Friedman test를 이용하여 집단간 차이를 분석하였다 (α = .05). **결과:** 가이드 드릴 사용 그룹의 각 시편에 대한 평균 성능 효율은 0.3861 - 1.1385 mm^3/s 범위를 보였고, 린드만 드릴 사용 그룹의 평균 성능 효율은 0.1700 - 0.4199 mm^3/s를 보였다. 가이드 드릴을 사용한 드릴 조합은 드릴링 시간으로 계산했을 때 우수한 성능 효율을 보였다 (P < .001). **결론:** 가이드 드릴 사용 그룹이 린드만 드릴 사용 그룹보다 우수한 성능 효율을 보였기 때문에, 1차 드릴링을 수행하는 과정에서 가이드 드릴의 사용이 더욱 적합하였다. (대한치과보철학회지 2022;60:143-51)

주요단어
치과 임플란트; 효율; 임플란트 핸드피스; 온도 변화

교신저자 손큰바다*, 이규복**
41940 대구광역시 중구 달구벌대로 2177
*경북대학교 첨단치과의료기기개발연구소,
**경북대학교 치과대학 치과보철학교실
*053-660-6925, **053-600-7674
*sonkeunbada@gmail.com,
**kblee@knu.ac.kr

원고접수일 2022년 1월 4일
원고최종수정일 2022년 3월 3일
원고채택일 2022년 3월 10일