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A Study on Temperature Changes during Bone Scaling and Cutting of Dental Ultrasonic Scaling/Surgery System

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치과용 초음파 스케일러/수술기 통합 시스템의 스케일링 및 절삭 시 온도 변화에 관한 연구

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ABSTRACT

While dental clinics still use the ultrasonic scaling/surgery tool for teeth scaling and cleaning the tool's use is expanding steadily to include treatment of damaged teeth and bone tissue. In this study, a handpiece moving system (HMS) was developed to evaluate bone scaling and cutting in the field of dentistry. The HMS, through a scaling test of bone using a scaler tip, it was able to identify surface damage. Additionally, a thermos-graphic camera was used to observe the temperature distribution that occurred during the bone scaling and cutting process. Consequently, we found that increasing the working load increased the amount of surface damage. Changes in temperature distribution occurred slowly and were maintained within safety bounds for 10 minutes. Going forward, we will compare the HMS performance on scaling and cutting with other devices.

Key Words : Handpiece Moving System(핸드피스 이송 시스템), Bone Scaling(골 스케일링), Scaler Tip(스케일러 팁), Ultrasonic Devices for Bone Surgery(초음파 골 수술기)

1. Introduction

In dentistry, dental calculus (also called oral biofilm, salivate, gingival sulcus, and dental plaque) refers to the minerals generally deposited on the surface of the teeth, such as fine food residue, microorganisms, or epithelial cells[1]. Daily tooth brushing, along with general cleaning by a dentist twice each year, are the most effective ways to remove dental calculus and so prevent gingivitis, pyorrhea alveolaris, and other diseases. Dental calculus also can be caused by stomatopathy because the possibility of residue in the mouth can go quite high. In this respect, early detection and treatment of teeth using a scaler instrument may slow the disease's progression and reduce the risk of further problems[2].

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Some orthodontic treatments require cutting the maxilla and mandibula. For that purpose, a bone cutter is used for operations. Moreover, doctors from various fields, including plastic surgery and otorhinolaryngology, are also applying the bone cutter in bone graft, cutting, and harvesting[3]. Previous studies suggest that using surgical instruments containing a piezoelectric oscillator can reduce a patient's complaints[4]. Therefore, the use of the piezo surgical instrument in dentistry, with its precision and high efficiency, is one of the most important requirements both for successful teeth scaling and bone cutting as it can decrease the risk of damage to blood vessels, nerves, or other tissues[5,6]. This piezo surgical instrument has been widely used in the operating frequency of 25~30 kHz[7]. The characterization of ultrasonic is to remove the cell walls of the cells in the periodontal pockets caused by shock waves produced with the collapse by pressure from it due to the cavitation effect of the generated bubbles[8]. Be that as it may, during a dental treatment, ultrasonic scaler tips can cause permanent damage to the pulp and teeth-supporting tissue[9,10]. There have been some reports on the safety and efficiency of the scaler tips used in the ultrasonic scaler testing instrument. For instance, Hong[10] evaluated the efficiency of calculus removal and the wear of scaler tips made of stainless steel, copper, and silver. The researcher reported that the efficiency of copper tip was higher than that of other tips. Back et al.[11] demonstrated the safety and efficiency of novel ultrasonic scaler tips when he tested them along with conventional stainless-steel and plastic tips on titanium surfaces. He found that the novel metallic copper tip caused minimal damage to the titanium surface. Ultrasonic devices for bone surgery (UDBS) have been evaluated for use in cutting tests of teeth or bone, and the results reported in previous literature. According to Harder et al.[12], there are data about cutting performance and increased temperature observed during the cutting action of the ultrasonic devices using UDBS. However, the study yielded relatively poor results. Insufficient data are reported with regard to the environmental settings, devices output, working load, and movement velocity.

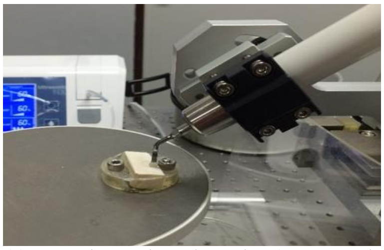
The focus of this study was to develop a new handpiece moving system (HMS) for precision testing, and to evaluate the characterization of experimental studies like temperature distribution during bone scaling and cutting by HMS after fabricating bone specimens.

2. Materials and Methods

2.1 Experimental set-up

2.1.1 Device

We used an Ultrasonic NX device developed by Micro-NX Co. Ltd., Korea. Fig. 1 shows the control box and handpiece parts of the Ultrasonic NX device[13]. The power, boost, and water buttons are for adjusting the bone scaling and cutting performance are also shown in Fig. 1(a, b).



(a) Experimental setting view(Bone cutting)

(b) Main control view

Fig. 1 Actual images of (a) Ultrasonic NX device and (b) Main control view

Table 1 Structural specification of the fabricated specimens

	Specimens
Shape	Disk
Mounting diameter	30
Mounting height	20
Bolt hole diameter	9.5

Table 2 Process conditions for bone scaling

	Scaler
Tip	D1*
Working load[N]	0.8
Working velocity[mm/min]	200
Contact angle[°]	10
Output[%]/ Amplitude[μm]	High(P100%/B100%)#/6
Distance[mm]	3

*D1 (Dmetec, Korea): for scaling in wide thick proximal surface

#P = Power; B = Boost

Table 3 Process conditions for bone cutting

	Tools
Tip	BS01*
Working load(N)	4
Working velocity(mm/min)	300
Contact angle(°)	90
Output(amplitude, μm)	6
Distance(mm)	5

*BS01: useful for osteotomy high efficiency

2.1.2 Specimens

The bone for the cutting test was obtained from a Korean native cattle's leg bone. Bone was washed in deionized water and 70% alcohol. The mixing materials for fixation of the bone materials were put together by mixing epoxy resin and hardener (Allied High Tech Products, Inc., USA) with a mixing ratio by weight of 100 for resin and 12 for hardener. A mold cup for mixing materials (approximately 30 mm in diameter and 10 mm in height) are prepared by removing an aluminum container of a small tealight candle. Table 1 shows the structured specifications of the fabricated specimens. Mounting diameter, height and bolting diameter of the fabricated specimens were 30, 20 and 9.5 mm, respectively.

2.1.3 Bone scaling test

The most widely used scaler tip in the dentistry field is the "D1". The tip-combined handpiece was fixed by a jig with a wrench bolt, and the specimen pinned on one side plate of a double balance. The force exerted by the bone was transmitted by a counterweight of a double balance with a working load of 0.8 N. To evaluate the bone damage, the operation of the X-Y axes was made using G-code. Feed rate and distance were 200 mm/min and 3 mm, respectively. The contact angle between the bone surface and tip was selected as 10˚. If contact between the tip and specimen lost focus, the bone damage test would fail and thus render the damage observation inaccurate. The power level selections were set to "medium" and "high", with water provided at the "medium" setting. Process conditions for the bone damage (scaling) test are shown in Table 2.

2.1.4 Bone cutting test

In the bone cutting test, a working load of 4 N was applied by placing a counterweight of 400 g near the center on the plate of a double balance. Through the G-code data by PC, working velocity was set at 400 mm/min, respectively. The surgery unit was set at "low", "medium" and "high" conditions. Boost was expressed in amplitude on the tip by applied voltage, and the distance for bone cutting was 5 mm. Table 3 presents the process conditions for the bone cutting test.

2.2 Experimental procedure

Bone scaling tests were prepared according to the experimental procedure reported in previous studies[10,12,14], and the experiment performed at room temperature (19˚C). The cooling irrigation solution used was by distilled water stored at room temperature (19˚C). The bone specimens were placed on the double balance and fixed by wrench bolt. The test tip was positioned parallel to the specimen surface. Operation of the HMS began immediately after the ultrasonic device was started. To confirm the temperature distribution on the bone specimens, a thermal camera was set on the side of an optical table. After testing, the specimens were dried in an oven for one day before observation from a scanning electron microscope (SEM).

2.3 thermal image analysis

The thermal imager (IRI 4010, IRISYS, Ltd., UK) used in experiments is also useful for measuring temperature distributions. The figures obtained were analyzed using IRISYS 4000 Series Imager' PC software.

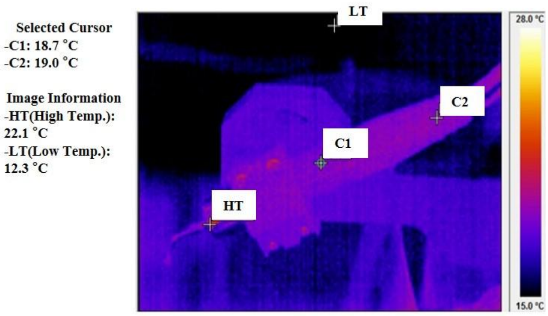
3. Results and Discussion

As temperature is involved in patient care, the ultrasonic surgery unit tool should be designed for the safety of the people who use it[15]. Heat generation of specimen and handpiece parts were studied by performing bone scaling and cutting tests using the Ultrasonic NX device for 2, 4, 6, 8, and 10 minutes. The amount of heat generated while operating the Ultrasonic NX device for 2, 4, 6, 8, and 10 minutes without moving test was compared to changes in heat regeneration during bone scaling and cutting at “high” setting conditions, as shown in Fig. 2. Temperatures on the handpiece part averaged 25.7˚C for 10 minutes. Despite the data obtained under the “high” setting conditions, these results suggest that the Ultrasonic NX device operates within safety parameters. Fig. 3 shows the temperature distribution at the handpiece and specimen for the bone scaling of Ultrasonic NX device for 2, 4, 6, 8, and 10 minutes. As shown in Fig. 3, the specimen during bone scaling exhibited temperatures for 2, 4, 6, 8, 10 min of 34.5˚, 32.6˚, 31.9˚, 31.9˚, and 29.3˚C, respectively, while handpiece exhibited temperature in the order of 31.7˚, 31.2˚, 31.1˚, 31˚, and 29.2˚C, respectively.

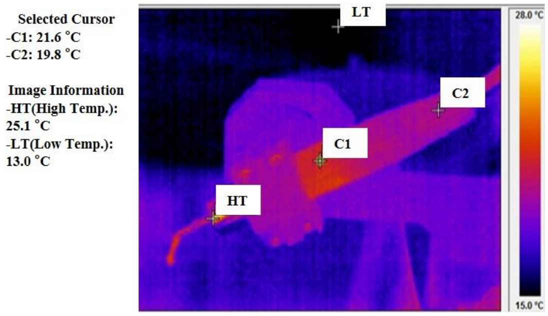
The specimen during bone cutting exhibited temperatures for 2, 4, 6, 8, and 10 minutes of 28.6, 28.5, 27.4, 29, and 28.1˚C, respectively, while the handpiece exhibited temperatures in the order of 31.7, 31.2, 31.1, 31, and 29.2˚C, respectively (Fig. 4). We confirmed whether temperature increased more than the initial temperature (25˚C) of the specimen and handpiece parts when compared with the measured temperature through the results shown in Figs. 3 and 4. The results indicated that there was no significant risk during dental bone scaling and cutting experiments. The difference may be due to the cooling effect provided by a regular water supply, influencing an overheated engine in specimen and handpiece.

According to Harder et al.[12], the main problem of the experimental set-up may cause thermal damage to the bone tissue by the bone cutting. They also said it needs to study how changes to a high temperature when using the surgery unit to perform the bone cutting. Eriksson et al.[16] said that it is likely that the bone resorption process cannot be reversed if exposed for one minute at 47˚C from the bone amputation.

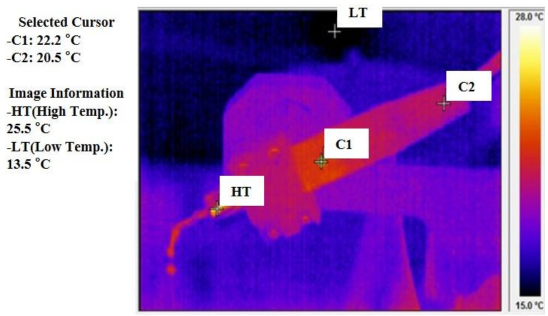
Increased temperatures of the specimen and handpiece in this study were similar to the intraosseous temperature changes observed during the cutting action of the three different ultrasonic devices of Harder’s research[12]. Consequently, the potential use of Ultrasonic NX’s device in dentistry and orthopedics was suggested.



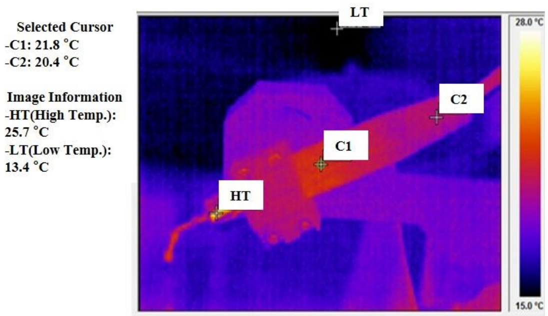
(a) Before operation



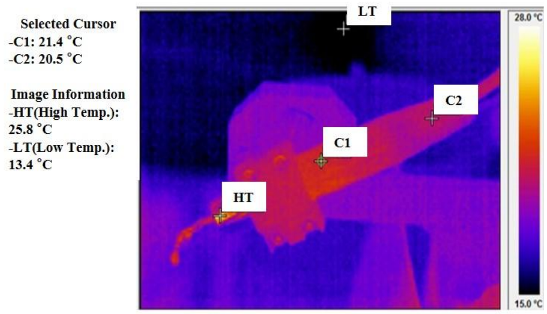
(b) After 2 min.



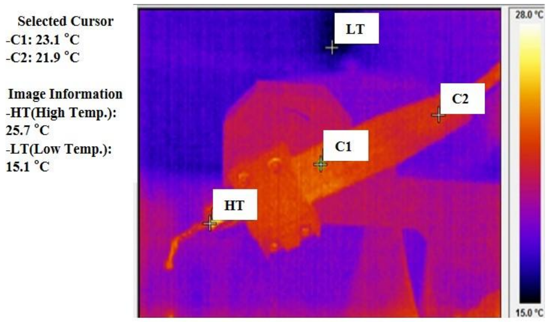
(c) After 4 min.



(d) After 6 min.

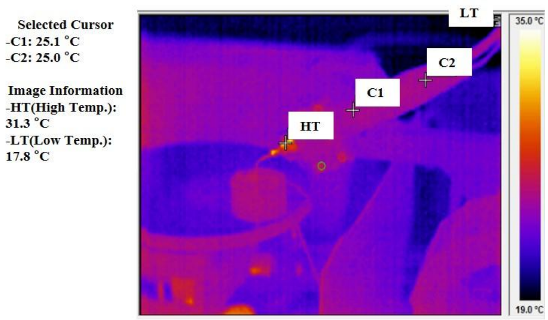


(e) After 8 min.

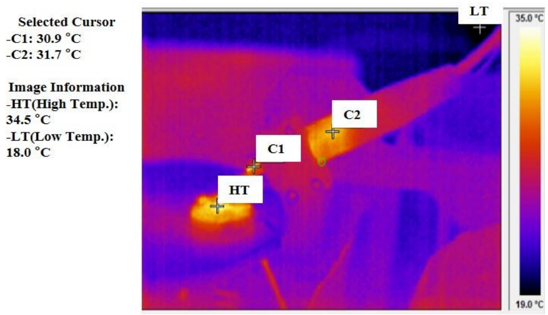


(f) After 10 min.

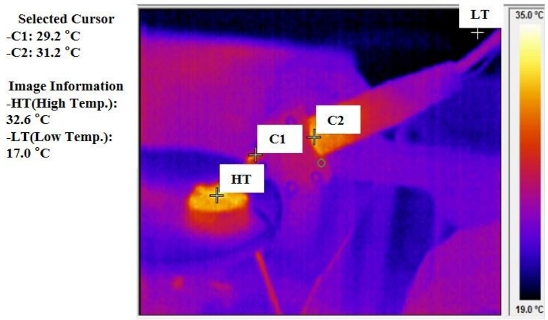
Fig. 2 Temperature occurrence of Ultrasonic NX device for 2, 4, 6, 8, and 10 min. without moving test



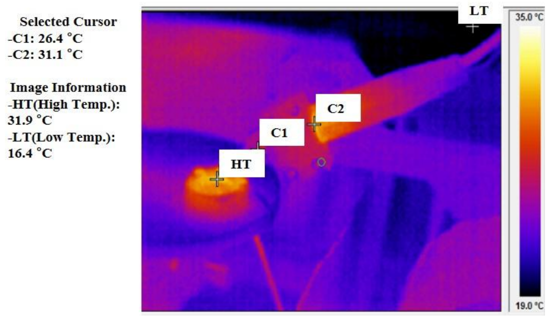
(a) Before operation



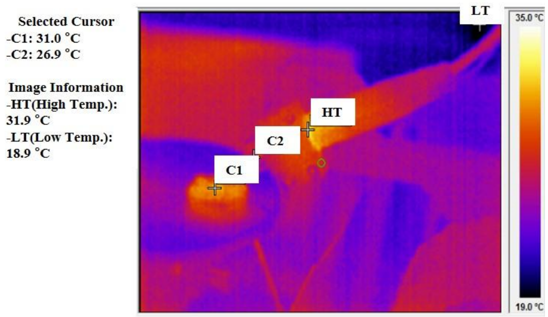
(b) After 2 min.



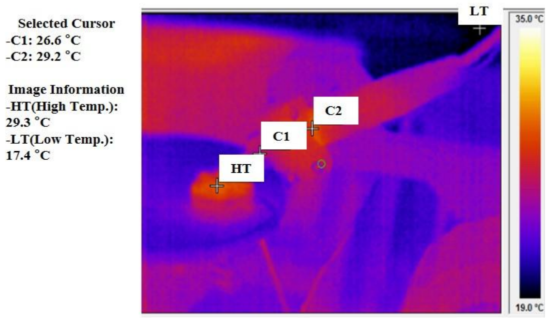
(c) After 4 min.



(d) After 6 min.

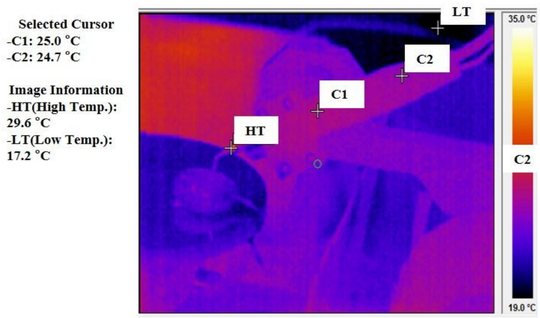


(e) After 8 min.

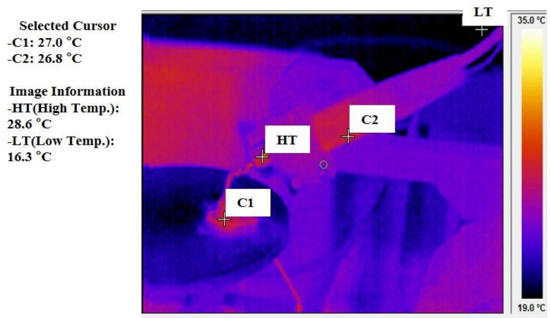


(f) After 10 min.

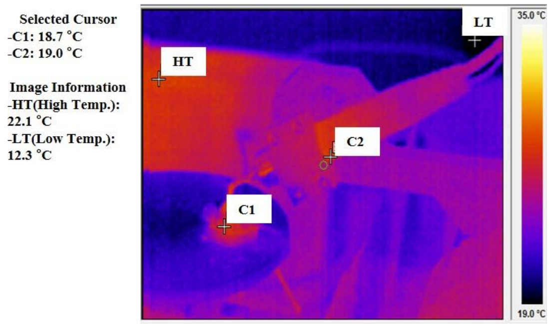
Fig. 3 Temperature occurrence at handpiece and specimen for bone scaling of Ultrasonic NX device for 2, 4, 6, 8, and 10 min.



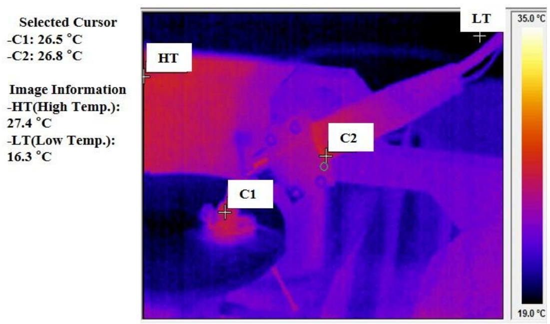
(a) Before operation



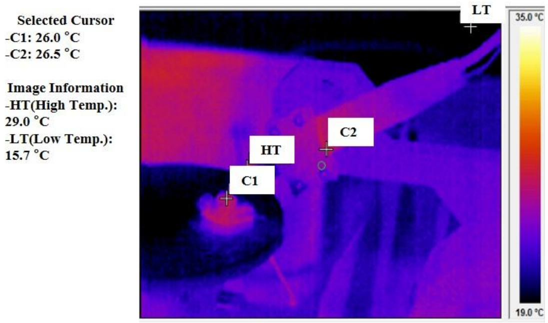
(b) After 2 min.



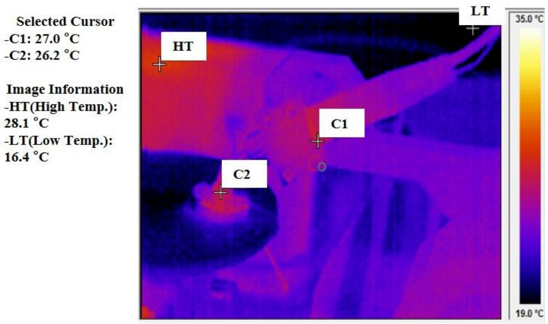
(c) After 4 min.



(d) After 6 min.



(e) After 8 min.



(f) After 10 min.

Fig. 4 Temperature occurrence at handpiece and specimen for bone cutting of Ultrasonic NX device for 2, 4, 6, 8, and 10 min.

4. Conclusions

In this study, bone scaling and cutting testing was successfully carried out using a dental ultrasonic scaling/surgery system. With regard to the bone scaling and cutting times of the tested HMS, we found that increasing the working time and output will damage the bone surfaces. However, the amount of heat caused by specimen and handpiece parts during the bone scaling and cutting when surgery was comparatively safe. Going forward, we will evaluate the mechanical performance on the bone damage and cutting compared with other ultrasonic scaling/surgery systems.

REFERENCES

1. Gurenlian, J. R., “The Role of Dental Plaque Biofilm in Oral Health,” Journal of Dental Hygiene, Vol. 81, No. 5, 2007.
2. Shaddox, L. M. and Walker, C., “Treating chronic periodontitis: current status, challenges, and future directions,” Clinical Cosmetic Investing Dental, Vol. 2, pp. 79-91, 2010.
3. Kenneth, W. Aschheim, “Esthetic Dentistry: A Clinical Approach to Techniques and Materials,” Book Aid International, 2014.
4. Vercellotti, T., “Technological Characterstics and Clinical Indications of Piezoelectric Bone Surgery,” Miverva Stomatologica, Vol. 53, pp. 207-214, 2004.
5. Lee, J.-H., Oh, J.-M., Hong, Y. W., Kim, S. K., Paik, J. H., Lee, Y.-J., Lee, J.-B. and Lee, S.-D., “Design and Evaluation of Ultrasonic Bone Surgical Instruments for Dental Application,” Journal of the Korean Institute of Electrical and Engineers, Vol. 25, No. 12, pp. 990-995, 2012.
6. Hennet, P., “Piezoelectric Bone Surgery: A Review of the Literature and Potential Applications in Veterinary Oral Maxillofacial Surgery,” Frontiers in Veterinary Science, Vol. 2, No. 8, 2015.
7. Magrin, G. L., Sigua-Rodriquez, E. A., Goulart, D. R. and Asprino, L., “Piezosurgery in Bone Augmentation Procedures Previous to Dental Implant Surgery: A Review of the Literature,” The Open Dentistry Journal, Vol. 9, pp. 426-430, 2015.
8. Leong, T., Ashokkumar, M. and Kentish, S., “The Fundamentals of Power Ultrasound-A Review,” Acoustics Australia, Vol. 39, No. 2, pp. 54-63, 2011.
9. Kwon, S. J., Park, Y. J., Jun, S. H., Ahn, J.-S., Lee, I. B., Cho, B. H., Son, H. H. and Seo, D. G., “Thermal Irritation of Teeth during Dental Treatment Procedures,” Restorative Dentistry & Endodontics, Vol. 38, No. 3, pp. 105-112, 2013.
10. Hong, J. W., “Effect of Wear on Tooth Surface and Efficiency of New Ultrasonic Scaler Tip,”

School of Dentistry, Master's Degree, Seoul National University, South Korea, 2013.
11. Baek, S.-H., Shon, W.-J., Bae, K.-S., Kum, K.-Y., Lee, W.-C. and Park, Y.-S., "Evaluation of the Safety and Efficiency of Novel Metallic Ultrasonic Scaler Tip on Titanium Surfaces," Clinical Oral Implants Research, Vol. 23, pp. 1269-1274, 2012.
12. Harder, S., Wolfart, S., Mehl, C. and Kern, M., "Performance of Ultrasonic Devices for Bone Surgery and Associated Intraosseous Temperature Development," The International Journal of Oral & Maxillofacial Implants, Vol. 24, No. 3, pp. 484-490, 2009.
13. Sa, M. W., Shim, H. R., Ko, T. J., Lee, J. M. and Kim, J. Y., "A Study about Experimental Evaluation of an Ultrasonic Surgery Unit for Bone Cutting," Journal of the Korean Society of Manufacturing Process Engineers, Vol. 15, No. 1, pp. 1-7, 2016.
14. Lea, S. C, Felver, V, Landini, G. and Walmsley, A. D., "Ultrasonic Scaler Oscillations and Tooth-surface Defects," Journal of Dental Research, Vol. 88, No. 3, pp. 229-234, 2009.
15. Cardoni, A., MacBeath, A. and Lucas, M., "Methods for Reducing Cutting Temperature in Ultrasonic Cutting of Bone," Ultrasonics, Vol. 44, pp. 37-42, 2006.
16. Eriksson, A. R., Albrektsson, T. and Albrektsson, B, R., "Heat Caused by Drilling Cortical Bone: Temperature Measured In Vivo in Patients and Animals," Acta Orthopaedica Scandinavica, Vol. 55, No. 6, pp. 629-631, 1984.