치의학석사 학위논문

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The use of pilot drills in sequential drilling of the osteotomy sites: is it really necessary?

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치의학과

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지도교수 : 구 기 태

이 논문을 치의학석사학위논문으로 제출함

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이성종

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Abstract

The use of pilot drills in sequential drilling of the osteotomy sites: is it really necessary?

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Purpose: This study investigated the effectiveness of multi-step drill for heat production during preparation of implant sites.

Materials and methods: 4 drilling experiments were carried out in this study. 2 experiments were conducted in conventional drilling sequence for the implant site of Ø4.3 and Ø4.6. And other 2 experiments were conducted in experimental drilling sequence for the implant site of Ø4.3 and Ø4.6. Conventional triflute drill and pilot drill were used in conventional drilling sequence and multi-step drill was used in experimental drilling sequence. 6 points of bovine femur were selected to measure the temperature during implant drilling. Temperature changes were assessed with infrared thermal-vision camera in real time. Each drilling sequence was performed 20 times. Thermal image data of experiment was transmitted to and analyzed by personal computer.

Results: Mean value of maximum temperature during experimental drilling sequence was 44.1℃ in Ø4.3 and 45.65℃ in Ø4.6. There were no significant differences of temperature elevation between conventional and experimental drilling sequence in the critical drilling step($p<0.05$). Outer part of the bone showed the highest temperature elevation during drilling.

Discussion and Conclusion: Within the limitations of this study, multi-step drill was used to shorten drilling sequence by omitting the pilot drilling step. In reference to the earlier results, two conclusions made. (1) There were no significant temperature differences between conventional and experimental drilling sequence. Mean maximum temperature during experimental sequence was below 47℃. That means several steps of the drilling can be shortened by using multi-step drill. (2) Multi-step drill will be very powerful and efficient tool that gives a lot of benefits. If we shorten the procedures of implant drilling by changing the shapes of fore-end of the drills, it will be more beneficial to not only clinicians but also patients.

Keywords: multi-step drill, implant, bone heating

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Contents

1. Introduction

Regulating the heat generation in the drilling sequence is the critical factor for the successful implant survival and osseointegration. Preparation of hard tissue for insertion of implants is mostly performed with cutting tools at a high speed. The frictional heat generated by such procedures will generally give rise to a zone of devitalized bone around the bur holes or osteotomies (Cordioli & Majzoub, 1997). Because of the low thermal conductivity of cortical bone, heat dissipation occurs slowly and temperature may remain elevated despite the use of external irrigation (Eriksson & Albrektsson, 1984). Bone is more susceptible to thermal injury than previously believed, and that temperatures in excess of 47℃ can result in osseous necrosis (Lundskog, 1972; Eriksson & Albrektsson, 1983).

The Branemark clinic for osseointegration implant treatment was established and the Branemark System has been well-received throughout the world (Sumiya et al., 1989). Many clinicians, based on the Branemark System, conduct several drilling steps in implant surgery and use various-sized drills not to exceed 47℃ that is reported as the threshold of bony necrosis. By enlarging the fixture site with the pilot drill, use of the twist drill is made easier. Repeat preparation sequence used for the twist drill when using the pilot drill.

From the clinical point of view, the usage of the pilot drill increases the drilling steps. Consequently, conventional implants technique need more time and energy and increase bone deletion. If the pilot drilling step can be omitted by using new type of drill without thermal damage to the bone, drilling sequence can be shortened. In attempt to solve these problems, multi-step drill was developed.

The purpose of this study was to compare existing drill with multi-step drill of heat generation during implant drilling.

2. Materials and methods

2.1 Drill design

Conventional triflute drills (Osstem Implant Inc., Busan, Korea) were used to perform conventional drilling process. Modified conventional triflute drills of multi-step shape were used to perform experimental drilling process. The design of the drill and schematic drawing is shown in Figs 1. There were two combinations of diameter in multi-step drill. MD2038 means the diameter of ØA is 2.0mm and ØD is 3.8mm. Identical principle can be adjusted to MD2043 (Figure 1).

2.2. System configuration

Multi-step drills (Osstem Implant Inc., Busan, Korea), artificial bone blocks (Sawbone, Washington, USA), drilling equipment (Hangil, Suwon, Korea), and infrared thermo-vision camera (Irisys, Northampton, UK) and control box were the components of overall system as shown in Figure 2. Test sample was bovine femur (cortical width 3mm). Soaking condition was 6

0℃, 3hr. Temperature of the bone before drilling were 32.19℃ in experimental sequence for Ø4.3, 32.25℃ for Ø4.6 and 32.6℃ in conventional sequence for both Ø4.3 and Ø4.6. The environment was 30℃ (average temperature of oral cavity referred R.A. Eriksson's study). Results of experiment were transmitted to and analyzed by personal computer (Figure 4).

2.3. Thermo-vision camera

The characteristic of the camera was real time measurement, uncooled type cooling, temperature range of -20.0℃~+300.0℃ (20°×20°), reading accuracy of ±2℃ or ±2%, resolution power of 0.1℃, wave length of 8㎛~14㎛, frame velocity of 16 frame/sec, and auto focusing. The distance between thermo-vision camera and the bone was 80㎜. Because thermo-vision camera measures radiation heat from the surface, the temperature must be measured as close as possible.

2.4. Temperature measurement

Identical 6 points of bone were selected in each drilling step to assess the temperature during implant drilling and measured by infrared thermo-vision camera. 6 points are sequential points that implant drill passes during drilling. 6 points were numbered in regular sequence from the outside to the inside as shown in Figure 5. Each point is square shape and 2.7mm ×

2.7mm size. The temperature difference between maximum and before drilling was calculated at every 6 points. The maximum temperature elevation among 6 points during drilling was selected as the value of each step.

The distance from the lateral border of the bone block to the drilling path was set to 0.3mm because temperature decreases were observed in areas exceeding 0.3mm (Oh et al., 2010). The depth of drilling was 15㎜ and the time of drilling was 2sec+0.1(minimum time that can be measured). Rotation speed of the drill was 1500 rpm(maximum rpm of Kavo^{R} engine) without irrigation.

2.5. Experimental procedure

4 drilling experiments were conducted and each experimentwas tested 20 times. 10 kinds of drilling steps were observed (Table 1) and the number of steps could be varied depending on drilling sequence. All drilling steps in the experiments were performed sequentially. Experiment 1-A was experimental drilling sequence for Ø4.3 and conducted in the order of step 8 and 10. Experiment 1-B was conventional drilling sequence for Ø4.3 and conducted in the order of step1, 2, 3, 4 and 5(Figure 2). Experiment 2-A was experimental drilling sequence for Ø4.6 (Figure 3) and conducted in the order of step 7 and 9. Experiment 2-B was conventional drilling sequence for Ø4.6 and conducted in the order of step1, 2, 3, 4, 5 and 6. Multi-step drill was used in the experiment 1-A and 2-A and the pilot drill was used in the experiment 1-B and 2-B (Table 2). The final step of experiment 2-B,

enlarging diameter from Ø4.3 to Ø4.6, was conducted following experiment 1-B in the same bone.

2.6. Statistical analysis

One-way (ANOVA) in SPSS 13.0 software program was used to compare several mean values because conventional drilling sequence has more than two steps and Scheffe test to find homogeneous subsets. However, experimental drilling sequence has two steps, independent t-test was chosen. ANOVA must be used when there were several drilling steps like experiment 1-B, 2-B and independent t-test must be used when there were only two steps like experiment 1-A, 2-A to compare mean values. To compare experimental sequence with conventional sequence, critical drilling step was selected from each drilling sequence by mean values. Critical step could be defined as mean maximum temperature elevation step.

3. Results

3.1. Mean maximum temperature in experimental drilling sequence

Mean bone temperatures before drilling were 32.19℃ in Ø4.3 and 32.25℃ in Ø4.6. Mean maximum temperatures after experimental drilling sequence were 44.1℃ in Ø4.3 and 45.65℃ in Ø4.6. The mean temperature changes were 11.91℃ in Ø4.3 and 13.40℃ in Ø4.6 (Table 3). In the 2 experimental drilling sequence, mean maximum temperatures were below 47℃.

3.2. The largest temperature rising drilling step in each experiment

Relating to bone necrosis, specific drilling step that had maximum temperature rising was evaluated. To find this critical step in each sequence, temperature elevation of all steps were calculated and statistical results by ANOVA and Scheffe test were used. Experimental sequences had only two steps, so independent t-test could be used. In the experiment 1-A, Step 8 showed more temperature increase (6.22℃) than Step 10 (5.69℃). Consequently, Step 8 was critical step of experiment 1-A. In the experiment 2-A, Step 7 showed more temperature increase (7.25℃) than Step 9 (6.15℃). Consequently, Step 7 was critical step of experiment 2-A. In the experiment 1-B, Step 4 showed especially maximum temperature rising (6.44℃). Consequently, Step 4 was critical step of experiment 1-B. In the experiment 2-B, Step 6 showed especially maximum temperature rising (7.51℃). Consequently, Step 6 was critical step of experiment 2-B (Table 1, Fig. 6).

3.3. Analysis of experimental and conventional sequence with critical step

The critical step of experiment 1-A was step 8 and experiment 1-B was step 4. In the independent t-test, the mean values of temperature elevation showed no significant differences between experiment 1-A and experiment 1-B, because Sig. value was larger than 0.05. Thus, two critical steps had same mean values ($p<0.05$).

The critical step of experiment 2-A was step 7 and experiment 2-B was step 6. In the independent t-test, the mean values of temperature elevation showed no significant differences between experiment 2-A and experiment 2-B, because Sig. value was larger than 0.05. Thus, two critical steps had same mean values ($p<0.05$).

3.4. The maximum temperature elevation point

Step 7 in the experimental sequence and step 6 in the conventional sequence showed the largest temperature elevation. Point 2 was the highest temperature rising (7.45℃) point in the step 6 and point 1 was the highest temperature rising (7.21℃) point in the step 7 (Fig. 7). There was the tendency that degree of temperature rising decreased from point 1 to point 6. The deepest point showed the lowest temperature rising in the most experiments. Heat generation and drilling depth were in inverse proportion to each other.

4. Discussion

The use of a graduated series of drills to widen the site has been recommended by the Scandinavian osseointegration group (Albrektsson, 1980; Albrektsson et al., 1985; Erikssonet al., 1982, 1983, 1984; Branemark P-I, 1983), and it was noted that this procedure results in only the removal of a small quantity of cortical bone, as the site has already been cut by the preceding bur in the series. However, clinicians need several drilling steps with conventional drill to avoid excessive heat generation.

Conventional drill showed a lot of problems in the clinical trials. The bone can be traumatized by the elevation of cutting heat. Clinicians can apply excessive force to the bone because of increasing cutting time. The errors of the drilling location can be occurred due to vibration. It is difficult to control drilling path. Clinicians also want to perform effective and time saving surgery by using new forms of drills. As a result, many companies tried to develop various forms of drills for more successful implant surgery. But there was no research of correlation between drill design and heat generation. In particular there was no research to reduce drilling step with newly developed drill. So, multi-step drill was used to test the possibility that can reduce drilling step without heat problem related to bony necrosis.

Conventional and experimental drilling sequences had different number of steps. The former had more than two steps and the latter had two steps. Thus, heat elevation by conventional sequence was analyzed with One-way (ANOVA) and experimental sequence with independent t-test. A simple comparison of temperature elevation between two sequences was meaningless because they were analyzed by different statistical method due to different number of variables. As a result, the mean maximum temperature elevation step was selected as critical drilling step in each sequence. The critical steps were the key steps that gave great influence on successful implants surgery without any problems related with heat. To investigate whether there was statistically significant difference in temperature elevation, critical step from each sequence was used to compare.

Our results from the analysis of conventional sequence and experimental sequence with critical step indicate that no significant differences were found. It demonstrated that the hypothesis which two sequences might have different mean values was rejected. The result from the mean maximum temperature in experimental drilling sequence, the mean maximum temperatures after drilling were under 47℃ without irrigation (Table 3.). So, temperature elevation might not exceed 47℃ in the actual performance with irrigation.

From the results of this study, when clinicians perform implant drilling of same size by either conventional or experimental sequence, no significant differences of heat generation occurred. We can therefore advance the results that pilot drilling is not essential step for reducing heat generation. The heat generation will be smaller by using multi-step drill because the force loading on the drill can be distributed to fore-end of the drill. Cutting temperature and final cutting amount of the bone chip might depend on the shape of fore-end of the drill. From the point of heat generation, multi-step drill showed excellent performance in the drilling sequence and gave the possibility to shorten drilling step. Thus, multi-step drill can be accepted in clinical use.

After implant drilling completely finished, temperature was measured because of residual heat. It could change the final temperature that we evaluated right after drilling (Watanabe et al., 1992). Prolonged friction would give rise to higher temperature increases, and differences in the bone structure between the superficial and deep aspects would produce different degrees of friction. The cortical bone that covers the external surface of bone is stronger and has a higher coefficient of friction compared with spongious bone. In addition, while drilling, the superficial aspect of a cavity would be subjected to frictional forces for a longer time than the deeper parts of the cavity. Therefore, considering duration, the deeper layers of the cavity were exposed to less friction, and thus the temperature rise was significantly lower than that at shallower level (Bedrettin et al. 2009). Our results indicate that selected 6 points of bone showed different heat generation and the shallower point showed the tendency of maximum temperature elevation. Therefore, superficial part of a cavity is more prone to thermal damage than deeper part.

All drilling steps were conducted sequentially because of technical difficulties in each experiment. In other words, there was time interval between drilling steps because drills in the drilling machine must be changed manually to progress next step. It was impossible to perform drilling without any time interval in actual clinical trial, so it was clear that there was cooling time. Therefore, the relapse of the temperature of the bone between drilling steps well reflected actual clinical situation. In this study, 4 drilling experiments were conducted in the no irrigation condition. Almost all the clinicians perform implant drilling in the irrigation condition (especially internal irrigation condition) not to exceed 47℃, known as the threshold of the bony necrosis in the previous study (Eriksson & Albrektsson, 1983). From a mechanical standpoint, heat was reported to induce microscopic dislocation and deformation of compact bone (Bonefield et al., 1968; Mauch et al., 1992; Rimnac et al., 1993).

However, Unexpected and uncontrolled errors could be occurred in-vitro test. For instance, irrigating the bovine bone equally was not easy work and there could be the large differences depending on the area that thermo-vision camera evaluated. Thermo-vision camera is a very sensitive method of measuring temperature changes, but it is effective only for measuring superficial temperature changes. Consequently, the cooling effect of the irrigation solution would mask the temperature measurements in deeper aspects of the drilling cavity (Bedrettin et al., 2009). Larger temperature elevation could be observed in the no irrigation condition rather than irrigation condition.

The limitations of this study were that conventional and experimental sequence was compared indirectly with critical step because they have different number of steps. Preserving temperature between drilling step in previous sequence was difficult because of multi-step cooling time. Therefore, evaluating the temperature rise of the entire sequence was limited.

5. Conclusion

Multi-step drill was used to shorten drilling sequence by omitting the pilot drilling step in this study. In reference to the earlier results, two conclusions made. (1) There were no significant temperature differences between conventional and experimental drilling sequence. Mean maximum temperature during experimental sequence was below 47℃. That means several steps of the drilling can be dramatically shortened by using multi-step drill without bone necrosis. (2) Multi-step drill will be very powerful and efficient tool that gives a lot of benefits. If we shorten the procedures of implants by changing the shapes of fore-end of the drills, it will be more beneficial to not only clinicians but also patients. Further studies to find optimal design of multi-step drill to clinical use needed.

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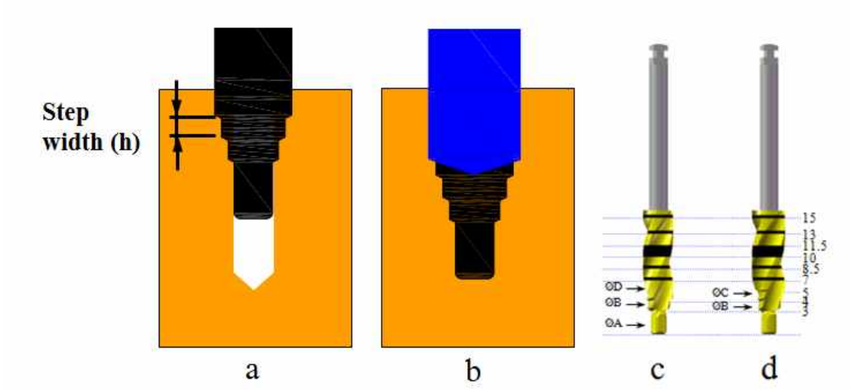
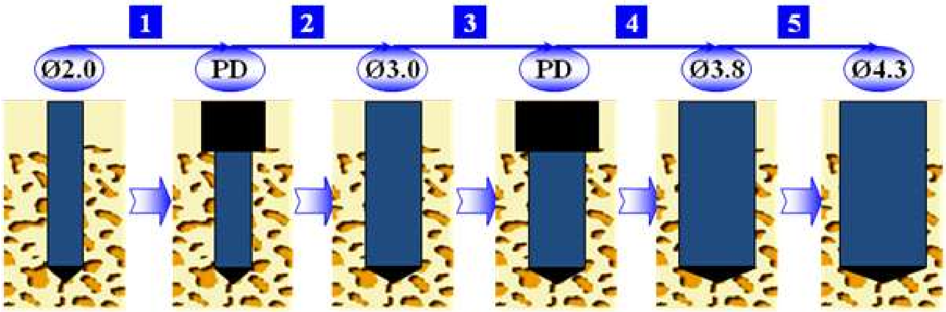
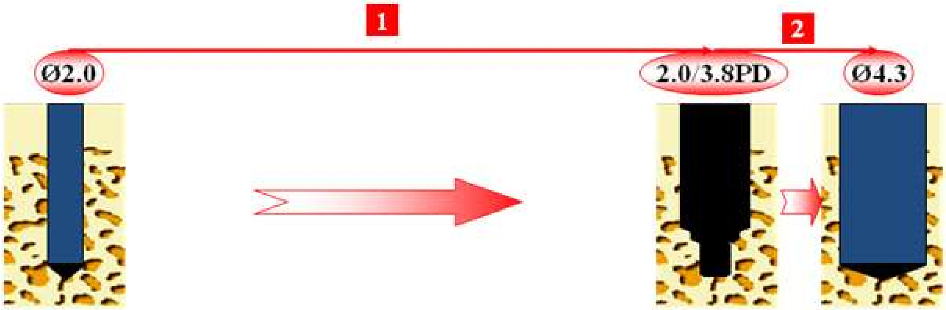


Fig. 1. Schematic drawing representing the design of multi-step drill. (a) After initial drill, multi step drill was used. (b) After multi step drill, final drill was used. (c) Experimental multi-step drill, MD 2038 where ØA is 2.0mm, ØB is 3.0mm, and ØD is 3.8mm. (d) Experimental multi-step drill, MD2043 where ØC is 3.8mm, and ØD is 4.3mm.

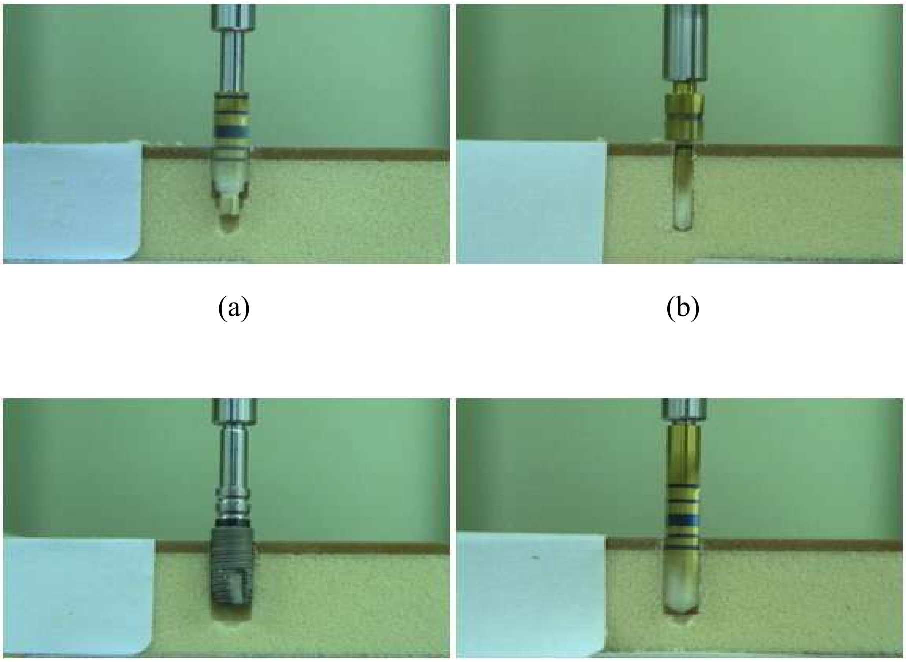


(a)



(b)

Fig. 2. Schematic drawing showing drilling sequence performed in this study for Ø4.3 (a) Conventional drilling sequence with conventional drill. (b) Experimental drilling sequence with multi-step drill.



(a) (b)

(c) (d)

Fig. 3. Experimental drilling sequence for Ø4.6 with multi-step drill. (a) Ø2.0 twist drill (b) Ø2043 multi-step drill (c) Ø4.6 twist drill (d) Ø5.0 fixture.

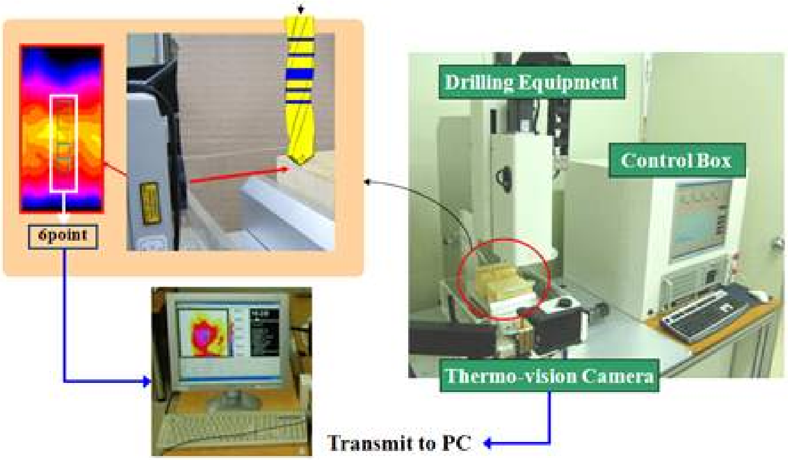


Fig. 4. Overall system configuration control box, drilling equipment, infrared thermo-vision camera, artificial bone block, implant drill and personal computer which analyzes the data.

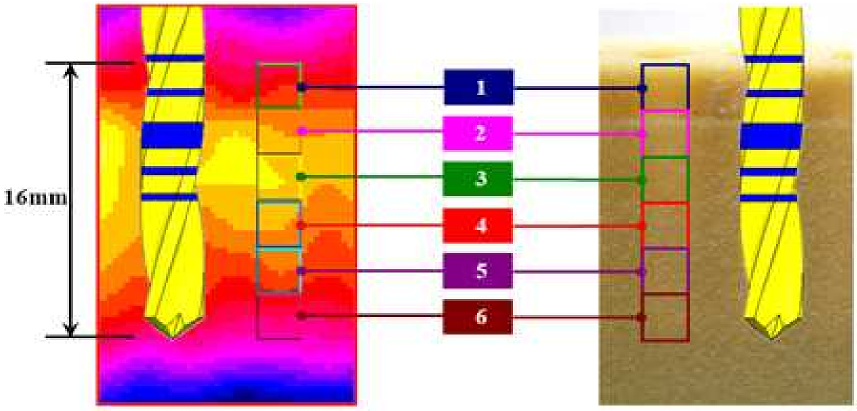


Fig. 5. Temperature measurement scheme; the selected 6 points for measuring temperature during drilling.

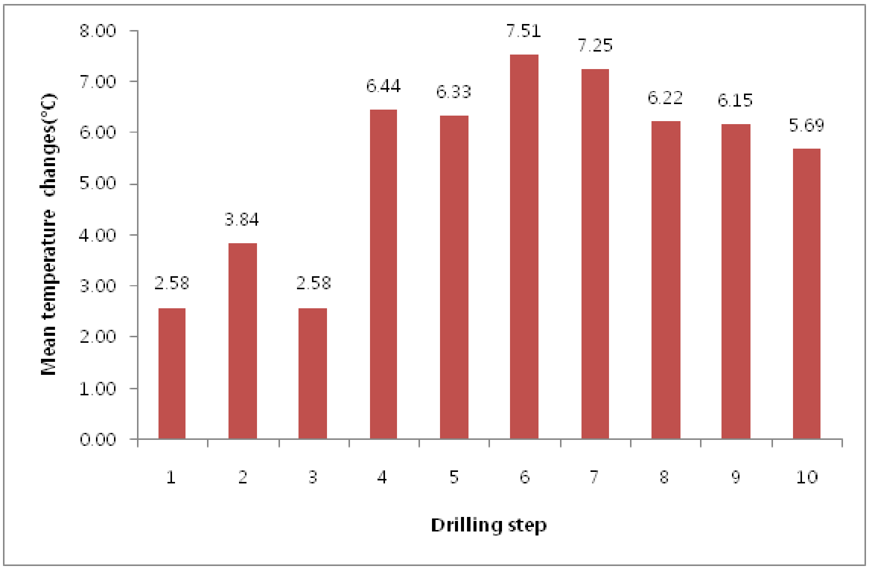


Fig. 6. Mean temperature changes by drilling step (1-10)

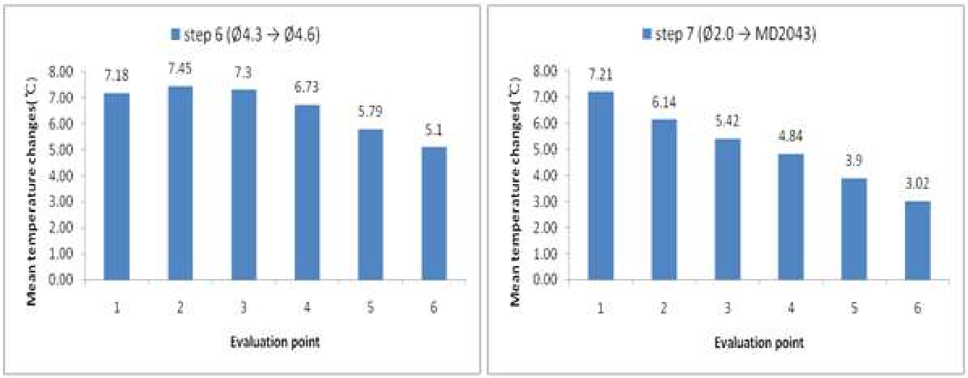


Fig. 7. Mean temperature changes at each point in critical step

Table 1. Drilling steps and comparison of temperature changes

Step	1	2	3	4	5	6	7	8	9	10
Last drill prior to evaluate	Ø2.0	PD2030	Ø3.0	PD3038	Ø3.8	Ø4.3	Ø2.0	Ø2.0	MD2043	MD2038
Drill under evaluation	PD2030	Ø3.0	PD3038	Ø3.8	Ø4.3	Ø4.6	MD2043	MD2038	Ø4.6	Ø4.3
Mean temperature change(°C)	2.58	3.84	2.58	6.44	6.33	7.51	7.25	6.22	6.15	5.69
Standard deviation of temperature change	0.27	0.51	0.21	0.45	0.82	0.86	0.66	0.73	0.87	0.85

(PD : Pilot Drill, MD : Multi-Step Drill)

Table 2. List of experimental and conventional sequences with involved step

Experiment	Sequence	Involved step
1-A for Ø4.3	Ø2.0 → MD2038 → Ø4.3	Step 8, 10
1-B for Ø4.3	Ø2.0 → PD2030 → Ø3.0 → PD3038 → Ø3.8 → Ø4.3	Step 1, 2, 3, 4, 5
2-A for Ø4.6	Ø2.0 → MD2043 → Ø4.6	Step 7, 9
2-B for Ø4.6	Ø2.0 → PD2030 → Ø3.0 → PD3038 → Ø3.8 → Ø4.3 → Ø4.6	Step 1, 2, 3, 4, 5, 6

(PD : Pilot Drill, MD : Multi Step Drill)

Table 3. Mean maximum temperature in experimental drilling sequence

	Sequence	
	1-A for Ø4.3	2-A for Ø4.6
Mean bone temperature before drilling (℃)	32.19	32.25
Mean maximum temperature after drilling (℃)	44.1	45.15
Mean temperature change (℃)	11.91	13.40
Standard deviation of temperature changes	0.83	1.08

국문초록

Osteotomy sites의 순차적 drilling시 pilot drill의 사용이 필수적인가?

목적: Multi-step drill을 이용한 drilling시 implant sites에서 열 발생을 측정하고 기존 drill과의 비교를 통해 pilot drill의 필요성에 대해 고찰해 본다.

방법 및 재료: 본 연구에서는 4종류의 drilling 실험이 수행되었다. 2개의 실험은 기존 drill을 사용하여 4.3mm와 4.6mm 직경의 implant site를 형성하는 것이고 다른 2개의 실험은 multi-step drill을 이용하여 4.3mm와 4.6mm의 implant site를 형성하는 것이다. Bovine femur에 drilling을 시행하였고, 적외선 열화상 카메라로 온도변화를 측정하였다. 각각의 drilling 실험은 20회씩 반복되었고, 컴퓨터를 통해 결과를 분석했다.

결과: 기존 drill을 사용한 경우와 multi-step drill을 사용한 경우 온도 상승에 있어 유의한 차이가 없었다. 또한 골 괴사 온도인 47℃를 넘지 않았다. drilling시 온도 상승이 가장 큰 부분은 cortical bone으로 구성된 bovine femur의 표면이었고, 깊이 들어 갈수록 온도 상승정도는 감소하였다.

고찰 및 결론: Multi-step drill을 사용한 경우와 기존 drill을 사용하여 drilling한 경우 온도 상승에 있어 유의한 차이가 관찰되지 않았다. 따라서 multi-step drill을 이용한다면 pilot drilling을 생략할 수 있어 drilling 단계를 획기적으로 줄일 수 있을 것이다. 이는 임상의뿐만 아니라 환자에게도 이익이 될 것이다.

주요어: multi-step drill, 임플란트, 골에서의 열발생

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