Comparison of Heat Generation Between Internally Guided (Cannulated) Single Drill and Traditional Sequential Drilling With and Without a Drill Guide for Dental Implants

Scott E. Bulloch, DDS, MS[1]/Russell G. Olsen, DPM[2]/Brandon Bulloch, BS[3]

Purpose: *To determine whether a wire-guided single drill protocol could be utilized without causing an increase in bone temperature beyond those seen with the traditional techniques of sequential drilling with and without a drill guide.* ***Materials and Methods:*** *A bovine femoral bone model was used with thermocouples and infrared temperature measurements to record thermal increase of the bone and drills during implant site preparation. Two thermocouples, one on each side of the osteotomy, were placed 1 mm from the outer diameter of the final drill. Drilling was performed at a constant speed (2,100 rpm) and pressure (2 kg) under continuous room temperature irrigation. Infrared temperature measurements of each drill were taken immediately before and after drilling. The six study groups included standard sequential drilling protocols for 3.5-mm and 4.2-mm final drills with and without the use of a surgical guide, and cannulated single drill technique for 3.5-mm and 4.2-mm drills. Statistical analysis was performed using a Tukey post hoc one-way ANOVA test. P < .05 was determined to be significant.* ***Results:*** *No significant difference in thermal increase was found between single drill cannulated implant site preparation and sequential drilling with or without the use of a drill guide for the 3.5-mm or 4.2-mm drilling sequences, respectively. The thermal increase was found to be significantly less for the 4.2-mm single drill compared with the 3.5-mm sequential drill with surgical guide (P = .046). Infrared temperature measurement revealed no significant difference in drill temperatures throughout the study.* ***Conclusions:*** *Cannulated single drill technique does not cause an increase in bone temperature greater than that seen with standard sequential drilling with or without a surgical guide.* INT J ORAL MAXILLOFAC IMPLANTS 2012;27:1456–1460

Key words: *bone, cannulation, dental implants, drill guidance*

Internal guidance using guide wires and cannulated drills has long been the preferred technique in many orthopedic procedures. This is especially true with regard to the more delicate and precise treatment of the smaller bones of the hands and feet.[1] This technology had previously not been adapted for use with the placement of dental implants. Cannulation as a general technique involves the placement of a guide wire such as a K-wire. This is most commonly done by drilling the wire into the bone in the desired location. Verification of location can then be accomplished radiographically. A drill with a hole through the entire length along the long axis and corresponding in size with the wire is then placed over the wire and drilling is accomplished as the drill follows the wire into the bone. Although traditional sequential drilling can be done with a guide wire, one of the advantages of cannulation is that the wire provides sufficient stabilization of the drill to allow single-drill site preparation. In this manner, the final drill is the only drill used for the osteotomy, significantly shortening the necessary drilling time. Multiple studies from orthopedic and oral surgery literature demonstrate that bone heating is increased as drilling time increases.[2–8]

Heat generation while drilling bone has long been recognized as a concern. Delayed healing as well as necrosis are among the complications associated with excessive drilling temperatures and duration. Motor speed, drill configuration and size, duration of drilling, irrigation techniques, use of surgical splints, along with many other factors, have been previously explored.[2–12] This study is unique in its comparative evaluation of thermal increase using a cannulation technique compared with traditional sequential drilling for the placement of dental implants. This study did not specifically compare the total drilling time associated with each technique.

[1]Oral and maxillofacial surgeon, private practice, St. George, Utah, USA.
[2]Podiatric surgeon, private practice, Cedar City, Utah.
[3]Student, laboratory assistant, Dixie State College, St. George, Utah, USA.

Correspondence to: Dr Scott E. Bulloch, 754 S Main #5, St. George, UT 84770, USA. Fax: 435-652-0138. Email: oms@infowest.com

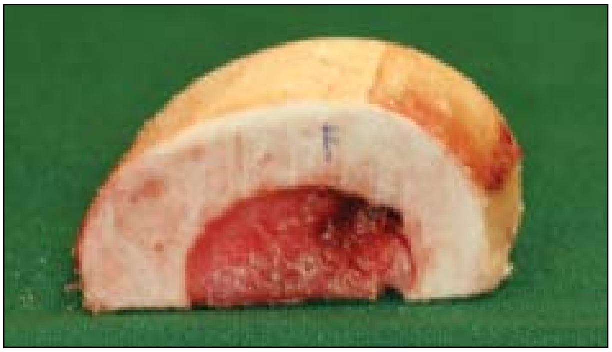

Fig 1 Bovine femoral bone segment.

Fig 2 Surgical guide.

MATERIALS AND METHODS

Uniform thickness bovine femoral cortical bone segments were used for this study (Fig 1). Bone segment use and sequence were randomized into one of six study groups as follows: Group A, sequential drilling up to 3.5 mm with the use of a surgical guide; Group B, sequential drilling up to 3.5 mm without the use of a surgical guide; Group C, 3.5-mm single cannulated drill; Group D, sequential drilling up to 4.2 mm with the use of a surgical guide; Group E, sequential drilling up to 4.2 mm without the use of a surgical guide; and Group F, 4.2-mm single cannulated drill (see Table 1). New drills manufactured by Straumann (Straumann USA) were used in this study. The cannulated drills were modified by the investigator for use with 0.8-mm guide wires. Sequential drill sizes consisted of 2.2 mm, 2.8 mm, 3.5 mm, and 4.2 mm when indicated. Groups A and D utilized the Straumann Surgical Guide kit (Straumann USA). The guide splint was fabricated using an acrylic disk that fit tightly around the individual guide sleeves (Fig 2). Red wax was used between the acrylic disc and the bone to simulate gingiva and to adapt the disk to the bone. In order to eliminate directional variations in drilling, a drill press was utilized for all drilling. Drilling was accomplished at a constant speed of 2,100 rpm, and a jig was fabricated to provide a constant 2-kg drilling pressure. Fifteen drilling sequences were completed for each group in random order for a total of 90 trials. Holes of 0.8 mm were drilled to a depth of 8 mm on both sides of the planned drilling site. These holes were positioned 1 mm outside the diameter of the final drill (5.5 mm apart for the 3.5-mm drilling sequences, and 6.2 mm apart for the 4.2-mm sequences). K type micro thermocouples (Omega Engineering) were placed into the holes and secured and sealed from moisture using silicone sealant (Fig 3). A handheld data logger (Omega HH147U) was used to collect constant temperature data for both thermocouples (T1 and T2) which was recorded on a laptop computer throughout the study. Temperature change from predrilling (Start T1 and Start T2) to finish was collected for all drills in all sequences, and a maximum temperature was identified for each thermocouple (T1 Max, and T2 Max). Thermocouple readings were evaluated and the difference between the start and maximum temperatures were recorded as ΔT1 and ΔT2. These two temperatures were averaged for each drill. Drilling sequences were evaluated by comparing the start temperatures (prior to the pilot drills) and the maximum temperature reached throughout the sequence. This provided a cumulative maximum temperature increase (cumulative T Max) for the sequence. An infrared temperature gun (Fluke 62 Mini IR Thermometer) was used to measure the starting and ending temperatures of each drill before and after drilling with irrigation. Irrigation consisted of room temperature water in a continuous flow with irrigation syringes. Cannulated drilling was accomplished by drilling a 0.032-inch (0.8 mm) wire into the bone. This was

Table 1 Study Groups

Group	
A	Three drill sequence of 2.2-mm, 2.8-mm, and 3.5-mm drills with guide splint
B	Three drill sequence of 2.2-mm, 2.8-mm, and 3.5-mm drills
C	Single 3.5-mm cannulated drill
D	Four drill sequence of 2.2-mm, 2.8-mm, 3.5-mm, and 4.2-mm drills with guide splint
E	Four drill sequence of 2.2-mm, 2.8-mm, 3.5-mm, and 4.2-mm drills
F	Single 4.2-mm cannulated drill

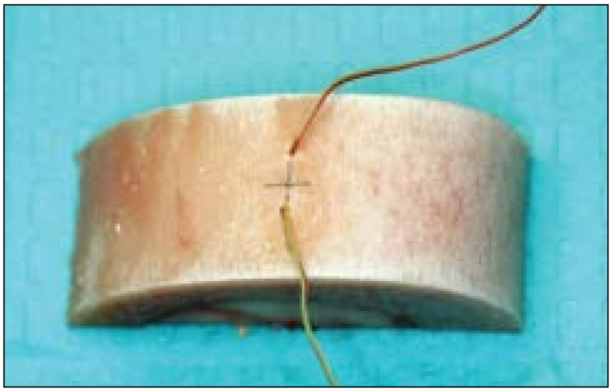

Fig 3 Microthermocouples in bone segment.

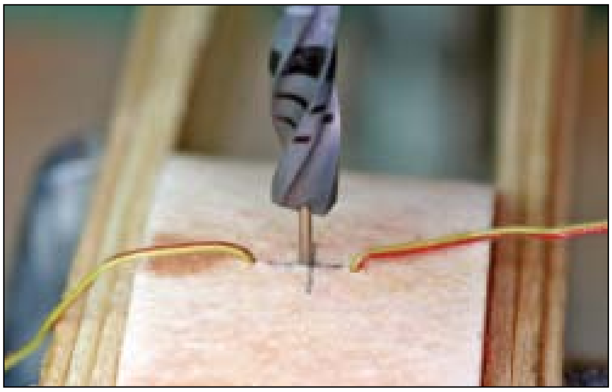

Fig 4 Cannulated implant drill and guide wire.

Table 2 Mean Maximum Temperature Increases (°C)

Group	Results
A	26.39*
B	23.3
C	23.69
D	21.84
E	22.94
F	14.77*

* Statistically significant

Table 3 Combined Mean Temperature Increases by Category (°C)

Category	Groups	Mean increase
Guided	A and D	24.12
Unguided	B and E	23.12
Cannulated	C and F	19.23

Table 4 Increase in Drill Temperature by Infrared Measurement (°C)

Group	Results
A	1.36
B	2.49
C	2.82
D	1.0
E	1.38
F	1.48

then followed by placing a 3.5- or 4.2-mm Straumann drill that had been modified by drilling a 0.032-inch hole through the long axis over the wire (Fig 4). All drilling sequences were taken to a depth of 10 mm. Statistical analysis was completed using a Tukey post hoc one-way ANOVA test.

RESULTS

The cumulative temperature increases in degrees Celsius were averaged for each of the six groups with the following results: Group A (3.5 guided sequence), 26.39; Group B (3.5 unguided sequence), 23.3; Group C (3.5 cannulated), 23.69; Group D (4.2 guided sequence), 21.84; Group E (4.2 unguided sequence), 22.94; and Group F (4.2 cannulated), 14.77 (Table 2). The combined averages for each technique were: guided sequence (groups A and D), 24.12; unguided sequence (groups B and E), 23.12; cannulated (groups C and F), 19.23 (Table 3). The difference between groups A and F was found to be statistically significant with $P = .046$. Infrared pre- and postreadings showed a minimal difference and were found not to be significant in any of the groups (Table 4). The start temperatures were noted to increase with each additional drill in a sequence indicating a tendency for bone to hold heat. The majority of the maximum temperature increases were noted with the pilot drills. The tendency was for a lower temperature increase with the larger diameter drills.

DISCUSSION

Wire guidance as a means of increasing drilling accuracy has been well established in various surgical disciplines. The effect of this technique on bone temperatures has not been previously evaluated compared with commonly used methods of bone drilling in preparation for placement of dental implants. Heat generation during drilling sequences has long been a known concern, and must be considered in the development of any placement technique.

Of interest is the fact that the largest temperature increase was noted with the use of the pilot drills during sequential drilling. Since all temperature measurements were taken beyond the extent of the final drills, this study refutes the concept that bone heating during the use of pilot drills is not significant because heated bone will be removed by subsequent drills. Possible explanations for this finding could include the fact that, at a constant pressure of 2 kg, the actual PSI at the drill tip would be many times greater for a 2.2-mm drill tip than for a 4.2-mm drill tip. Another possibility is that a smaller drill has smaller flute spaces which could restrict irrigation, thus decreasing its cooling effect. The difference in the mass of each drill is another potential factor since this could effect the heat storage or dissipation of each drill. Further investigation is needed to more thoroughly evaluate each potential factor. Of note also is the fact that, although necessary for standardization in this study, constant uniform pressure is seldom present in a clinical setting where pressure is generally lighter and variable.

The lack of significant variation in drill temperatures as measured by infrared temperature monitoring is most likely a measurement of the consistency of the irrigation cooling. An accurate measurement of drill heat increase in and of itself would require that the study be done without the use of irrigation.

Misir et al[12] demonstrated significantly higher heat generation with the use of surgical guide splints. This tendency was also seen in the present study, although the differences only reached statistical significance between groups A and F. This difference appears to be the result of a combination of increased drill size combined with the lack of a guide splint. The significance of each individual factor is thus unclear. This increased bone temperature was not seen with the use of wire guidance (cannulation).

Clinical Observations

Traditional drill guides most commonly guide the drills through the use of sleeves in a tissue borne splint. This approach has several inherent limitations. The splints generally block or limit the view of the surgical field. Maintaining stability of the splint can be complex and difficult especially when drilling into narrow or angled bone is required. The need to reflect soft tissue, or perform bone grafting procedures renders many splint designs ineffective or inaccurate. Tissue punch techniques required by some guide splints can remove needed attached gingiva, thus compromising the final result. Nonguided techniques also have their challenges. Freehand placement leaves great room for operator error and misalignment. The technique of radiographically evaluating the placement of a pilot drill prior to further drilling can be useful; however, redirecting the misdirected pilot drill can be difficult due to the tendency for the drill to follow the path of the initial drill hole. Correct pilot drill angulation can be especially difficult to achieve in angled bone, such as fresh extraction sites, or in very narrow bone like a knife-edge ridge. Cannulation wire guidance has several advantages. Due to the sharp tip and small diameter of the guide wire, it can be more easily drilled into narrow or angled bone. Angulation errors can be corrected more easily due to a decreased tendency to follow previous holes. Wires can be placed with the use of a traditional guide splint, and then the splint is removed. At that time, the wires become a bone-borne rather than a tissue-borne guide, thus allowing for tissue reflection, bone grafting, etc, without loss of guidance accuracy. The operator has full unobstructed visualization of the surgical field throughout the drilling process. The depth of placement of the wires may be used as a guide for drilling depth with radiographic verification. Wires guide the drill tip with tremendous accuracy, thus eliminating any drill walk during drilling of narrow or angled bony walls. Parallelism or desired angle variations can be determined in the lab and accurately duplicated with the wires in the clinical setting. This, along with single drill implant site preparation, can significantly increase the accuracy of implant position and angulation while decreasing surgical time and bone trauma. The use of wire guidance requires technique modification and additional precautions when approaching vital structures, but is easily adaptable to most implant cases.

CONCLUSION

This study demonstrates that wire guidance with a single drill can be reliably performed without causing bone heating greater than that seen with standard drilling techniques under similar circumstances. Possibilities for implant site preparation, as well as the long term safety record of cannulation in orthopedic procedures, suggest that this is a technique that warrants further investigation.

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REFERENCES

1. Franssen BB, Schuurman AH, Van der Molen AM, Kon M. One century of Kirschner wires and Kirschner wire insertion techniques: A historical review. Acta Orthop Belg 2010;76:1–6.
2. Fuchsberger A. Damaging temperature during the machining of bone [in German]. Unfallchirurgie 1988;14:173–183.
3. Brisman DL. The effect of speed, pressure, and time on bone temperature during the drilling of implant sites. Intl J Oral Maxillofac Implants 1996;11:35–37.
4. Abouzgia MB, James DF. Temperature rise during drilling through bone. Intl J Oral Maxillofac Implants 1997;12:342–343.
5. Iyer S, Weiss C, Mehta A. Effects of drill speed on heat production and the rate and quality of bone formation in dental implant osteotomies. Part II: Relationship between drill speed and healing. Intl J Prosthodont 1997;10:536–540.
6. Bachus KN, Rondina MT, Hutchinson DT. The effects of drilling force on cortical temperatures and their duration: An in vitro study. Med Eng Phys 2000;22:685–691.
7. Augustin G, Davila S, Mihoci K, Udiljak T, Vedrina DS, Antabak A. Thermal osteonecrosis and bone drilling parameters revisited. Arch Orthop Trauma Surg 2008;128:71–77.
8. Sharawy M, Misch CE, Weller N, Tehemar S. Heat generation during implant drilling: The significance of motor speed. J Oral Maxillofac Surg 2002;60:1160–1169.
9. Yoshida K, Uoshima K, Oda K, Maeda T. Influence of heat stress to matrix on bone formation. Clin Oral Implants Res 2009;20:782–790.
10. Bubeck KA, García-López J, Maranda LS. In vitro comparison of cortical bone temperature generation between traditional sequential drilling and a newly designed step drill in the equine third metacarpal bone. Vet Comp Orthop Traumatol 2009;22;442–447.
11. Cordioli G, Majzoub Z. Heat generation during implant site preparation: An in vitro study. Intl J Oral Maxillofac Implants 1997;12: 186–193.
12. Misir AF, Sumer M, Yenisey M, Ergioglu E. Effect of surgical drill guide on heat generation from implant drilling. J Oral Maxillofac Surg 2009;67:2663–2668.