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Comparison of Heat Generated During Twist Drilling Protocol by Guided and Non-Guided Implant Surgery

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Comparison of Heat Generated During Twist Drilling Protocol by Guided and Non-Guided Implant Surgery

by

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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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CONTENT

FIGURES

Figures Page

TABLES

Tables Page

ABSTRACT

Introduction: Guided implant surgery is becoming more prevalent among clinicians and is crucial for cases in which there are concerns about the proximity of the implant to vital anatomical structures, esthetic concerns, and the amount/quality of bone available. Surgical guides help with the angulation and positioning of the implant through the use of a CBCT scan and digital intraoral impression. However, there are some drawbacks with guided surgery. Heat that is generated during the osteotomy is one of the issues that has been of concern. The guide acts as a shield against the water irrigation from reaching the osteotomy site where the water acts as a cooling agent. The concern is that the guide will not allow proper water to flow and that the extra heat that is generated will have a deleterious effect on the bone.

Purpose: This study was conducted to evaluate and compare the heat generated during the initial pilot drilling for surgical guides versus free-hand implant surgery.

Materials and Methods: Blocks of approximately 35 x 18 mm bovine rib bone were used to replicate the human mandible. Alginate impressions were taken of the bone samples in order to get stone models of the bone. Then a light-cured resin material was used in order to fabricate the surgical guide. The surgical guides were planned to have initial, pilot guide holes for the implant drills. There were two groups that were tested with either a surgical guide or with a freehand surgical method. Real time temperature measurements were recorded directly before and after the drilling by a second operator. The depth of the drilling was done to approximately

8-10 mm from the base of the surgical guides. 50 temperature readings were recorded for both groups by a second operator.

Results: The results showed a mean temperature change of -1.27 ± (0.75) for the guided group and 1.37 ± (0.85) for the non-guided group. An independent t-test showed no significant difference with $p=0.55$ (Table 1).

A one-way analysis of variance analysis (ANOVA) was done to test the mean temperature change between bone blocks used. No significant difference existed with a $p=0.86$ (Table 3, Figure 4).

Conclusion: There was not a statistically significant temperature change when comparing the guided and non-guided groups. It can be concluded from this study that with proper irrigation, there is not a significant temperature change when comparing using a guide and not using a guide for the initial pilot drill.

CHAPTER ONE

INTRODUCTION AND REVIEW OF THE LITERATURE

Dental implants have provided another viable treatment option in treating edentulous spaces and incredible advances in implant dentistry have been made over the last thirty years. There have been improvements in areas such as esthetics and predictability during the surgery. Surgical guides have become advocated due to the significant improvements in implant placement accuracy, time efficiency, and reduction in surgical error. This all leads to a successful placement of a restoratively driven implant.[1]

The heat produced during the osteotomy was studied in the past and it has been concluded that the osteotomy causes an area of devitalized bone around the surgical site[2]. The temperature at which the bone necrosis occurs through the degeneration of some proteins when it reaches 47°C or higher for 1 minute. Once this temperature is reached, bone is replaced with fat cells that could prevent implant incorporation. As a result, implant failure occurs due to the overheating at the surgical site as fibrous tissue forms at the interface between the bone and implant.[2] Another study also showed that overheating the bone matrix caused an increased area of dead osteocytes and the regeneration of the periosteal membrane was delayed.[3]

Various factors have been studied in regard to heat production at the surgical site: drill configuration and size[4], irrigation technique[5], motor speed[6], and repeated use of implant drills[7]. A study completed by El-Kholey et al. showed that the there was no significant difference in the temperature increase with the simplified drilling technique when compared to the conventional drilling sequence.[8]

Drill speed is another issue that has been investigated as a possible cause of overheating of the bone during the osteotomy.[6] Different drilling speeds has an effect on early bone healing as overproduction of heat negatively affects bone healing. It is suggested that too low or excessively high drilling speeds generates higher compression and subsequent heat generation. There is an inverse relationship between the time spent on drilling and the rotational speed of the drill. This would infer that a lower drilling speed generates more frictional heat when compared to higher drilling speeds.[9] A study completed by Yeniyol et al. evaluated the effects of different drilling speeds on early bone healing in dogs in which they found that 1000 rpm yielded the strongest biologic response. They concluded that drilling speeds affected early osseointegration and higher drilling speeds presented the best biologic responses.[10] The biologic rationale for this is due to the existence of the necrotic bone tissues that causes osteoclastogenesis before osteogenesis. The faster drilling speeds creates lower necrotic bone residues and may actually induce direct osteogenesis.[11]

Many clinicians control the temperature from reaching 47°C using irrigation either internal or external during the surgery.[12] It has been observed that insufficient irrigation can cause a large area of resorption of the cortical bone leading to implant failure.[13] A concerning finding was lower values of bone to implant contact percentage when irrigation was not adequate. Another important aspect to consider is the use of internal or external irrigation for the cooling. A recent *in vitro* study found a significant difference in favor of internal irrigation. However, this study concluded that both internal and external irrigation provided efficient methods of cooling the temperature. Poor forms of irrigation can cause thermal damage on cortical bone that causes peri-implant bone resorption and possible failure.[14] The problem arises if a surgical guide inhibits the drilling area from the irrigant, which could interfere with the temperature control.

With the current direction of surgeons using surgical guides for placing dental implants, there is a need to investigate the amount of heat generated during the osteotomy. The benefits of using the computer guided surgical guides during implant surgery could be outweighed by the possible detrimental effect from heat production.[15] The aim of the present study is to compare the heat generated with a surgical guide and without a surgical guide during the initial osteotomy. The main area that this study will focus on is the initial contact between the drill and the bone, the cortical layer. This is where the external irrigation will play a major role in temperature control as it may be inhibited by the surgical guide.

Null Hypothesis:

There is no difference in the temperature change during the osteotomy between the guide and non-guided free hand groups.

CHAPTER TWO

MATERIALS AND METHODS

For this study, bovine ribs were used due to a previous study showing a similar thermoconductivity to the human mandibular jaw bone.[16] All bone pieces were obtained from a local butcher shop and cut into approximately 36 x 24 mm pieces. Six bone blocks with a cortical thickness of 2-3 mm were chosen for this study and were stored at -10°C in order to preserve the thermophysical properties.[17]

Alginate impressions were taken of the bone blocks that were going to be drilled with a surgical guide and stone models poured up. The surgical guides were fabricated using a visible light-cured resin (Dentsply Sirona LLC, Charlotte, NC. USA) using the stone models to accommodate a 2.0 mm twist drill (Nobel Biocare USA LLC, Yorba Linda, CA. USA)(Figure 1). No metal sleeves were used for the surgical guide. A total of 50 osteotomy sites were planned to be 3 mm apart.

For the free hand drilling sites, 50 markings that were 3 mm apart were made on the bone blocks with a pen a day before the experiment. Each of the osteotomy sites also had a control site that was approximately 1 mm away from the osteotomy and was approximately 8 mm in depth. In order to measure the temperature change during the drilling in bone near the osteotomy, control sites were prepared prior to the experiment at each osteotomy site. The control sites were approximately 1 mm away from each osteotomy site and was approximately 2 mm in diameter. The thermocouple probe was inserted approximately 3 mm into the control sites in order to measure the temperature at the entrance of the osteotomies.

The bone blocks were thawed at room temperature and then transferred inside a plastic bag into a water bath (PolyScience Inc. Niles, Illinois. USA) to get them to a standardized baseline temperature of 36°C for one hour before the experiment. A new drill was used for each osteotomy site. The drilling for the osteotomy was performed with a 2.0 mm twist drill according to their manufacturer's instruction of 800 RPM and an in-and-out motion to ensure proper irrigation for the drill. External irrigation was done with refrigerated saline water that was kept in a refrigerator between 2 and 10°C in a constant and profuse manner. The baseline temperature was taken in the control sites prior to the experimental osteotomies and once the target temperature of 36°C was achieved, the experimental drilling was initiated. The temperature of the bone was measured directly in the control sites during the osteotomy by one examiner using a digital thermocouple sensor (Extech SDL200 four-channel thermometer, Extech Instruments, Melrose, MA)(Figure 2, 3). The 4 channel, Ktype, digital, thermocouple probes have the ability to measure temperature ranging from -30°C to 300°C with a resolution of 0.1°C. The thermocouple probes were connected to a thermocouple sensor that allowed for constant real-time temperature readings. The thermal change was gathered from the difference of the initial temperature reading with the final temperature reading once drilling was completed by the examiner. Drilling was completed when approximately 4 mm of the drill penetrated into the bone samples. This was determined by a pre-existing mark on the drill and the top of the surgical guides. Two temperatures were recorded for each experimental osteotomy.

Statistical Analysis:

Descriptive statistics were calculated that included the mean and standard deviation. A paired t-test was used to compare the temperature change between the guided and non-guided groups. A one-way analysis of variance (ANOVA) was used to compare the temperature change between the different bones that were used. All statistical analyses were done using the IBM SPSS 26 (Armonk, New York, United States). Statistical significance was set at $p<.05$.

CHAPTER THREE

RESULTS

A total of 100 osteotomies in 6 bone blocks were made in the guided and non-guided groups. The temperature change was measured by one examiner who recorded the baseline and the final temperature after the drilling was completed.

The mean temperature change and standard deviation for guided group was -1.27 ± 0.75°C, and -1.37 ± 0.85°C for non-guided group. Independent t-test showed no significant difference in temperature change between the guided and non-guided groups with $p=0.55$ (Table 1, Figure 4).

The mean temperature change and standard deviation for each bone block was compared with ANOVA (Table 2). No significant difference existed with a $p = 0.858$ (Table 3) in both the guided and non-guided groups.

CHAPTER FOUR

DISCUSSION

The results of this study accept the null hypothesis that there is not a significant difference in the temperature change between the guided and non-guided groups for the twist drill protocol.

An important observation from this study was that constant irrigation on the drill must be achieved when the drill is utilized in an in-and-out motion. The examiner recording the temperature change confirmed that the irrigant was constantly hitting the drill. This finding is in line with the study by Gabay[19] in which the results showed a rapid increase in temperature for dental implants that were placed without irrigation while the use of irrigation caused a decrease in the temperature. One of the negatives of the “up and down” motion used in this study was that the drill must be removed completed from the guide in order for the irrigation to completely flush the length of the twist drill. There was never a time where the temperature ever came close to the 47°C that has been shown to cause bone necrosis[1].

This study has its limitations as it was an invitro study model and the surgical guide was not fabricated with a sleeve for the drill. Another limitation was that the bone models were not able to be scanned in order to create a 3-D surgical guide that could be printed for use. Not being able to digitally print a surgical guide did not allow us to account for the thickness of the guide and accuracy of the osteotomies. The thickness is very important to note as a guide sleeve is at a minimum of 5 mm in depth and the thickness of the surgical guide for this study was approximately 3 mm. The thickness of the guide can have an impact on the temperature control by limiting the irrigant from reaching the osteotomy site. There are also many different variables that need to be accounted for when measuring temperature change for these types of guides: room temperature, variable thickness of the bone pieces and the ability to keep the bone temperature stable throughout the experimental osteotomies.

More studies are needed in order to replicate tooth-borne and mucosa-borne surgical guides that are used in clinical settings. With the surgical guide not showing a statistically significant increase in temperature, other factors such as the overuse of burs and temperature changes as the drill sizes increase need to be studied. Further research is needed where temperature change can be measured in actual patients in real-time as implant surgery is being performed.

CHAPTER FIVE

CONCLUSION

Within the limits of this study, it can be concluded that there is no significant difference in the temperature change between initial twist drilling using a surgical guide and not using a surgical guide. The reader should be cautioned in all of the limitations that were stated in the discussion regarding the final conclusion of this study. As long as there is a steady source of irrigation with an in-and-out motion while using the surgical guide, temperature during the osteotomy with a 2 mm twist drill will not reach the level of overheating the bone.

Figure 1. Twist Drill (2.0 x 7-15 mm)

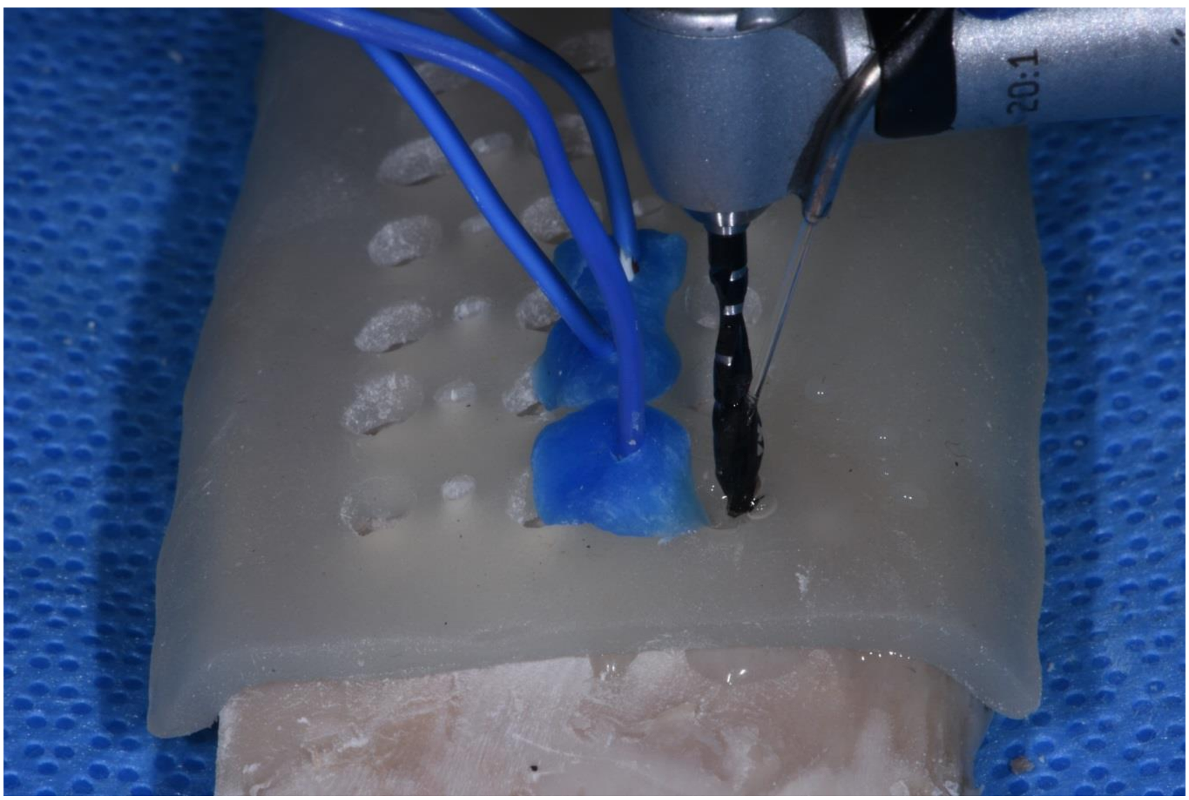

Figure 2. Bone with guide and refrigerated saline water

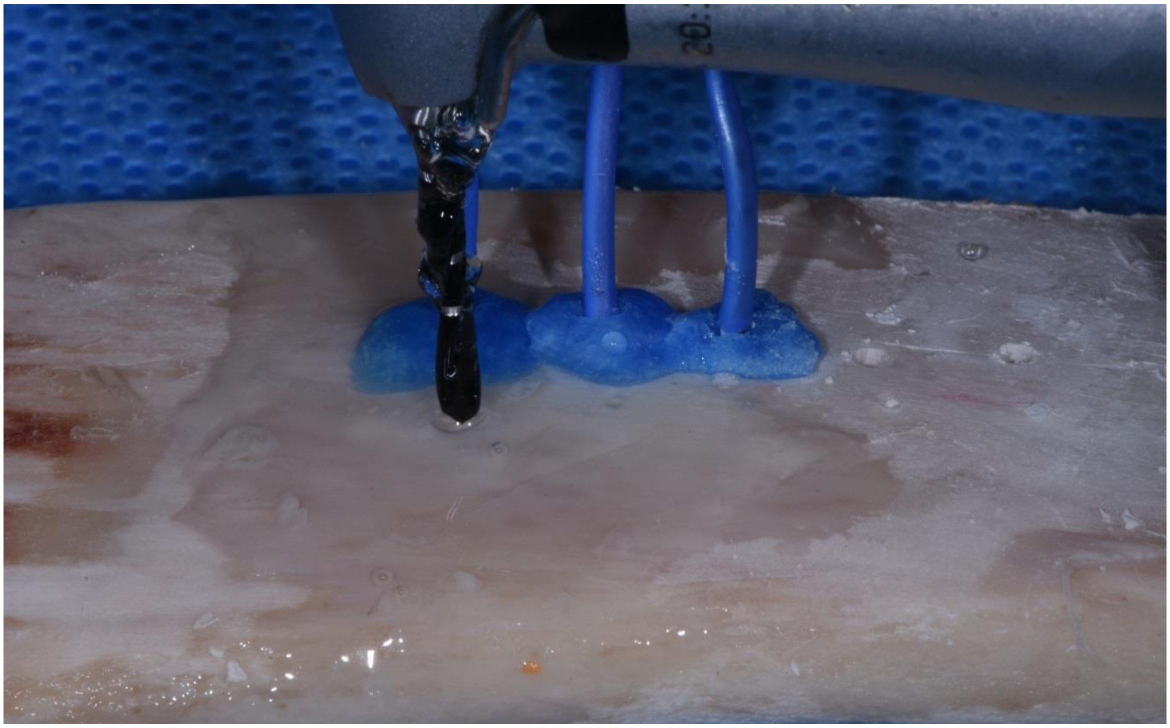

Figure 3. Bone without a guide and refrigerated saline water

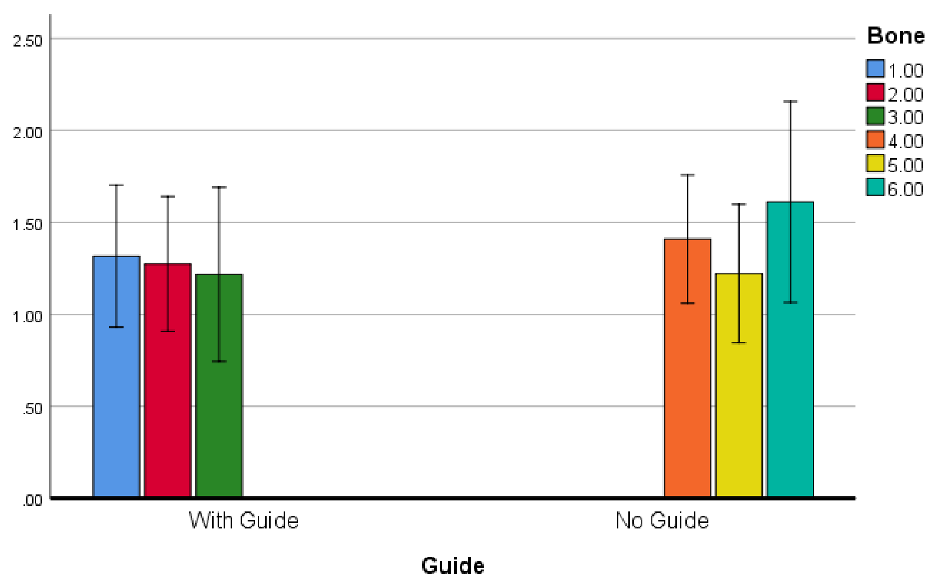

Figure 4. Boxplot of temperature change in all bone samples with and without a guide

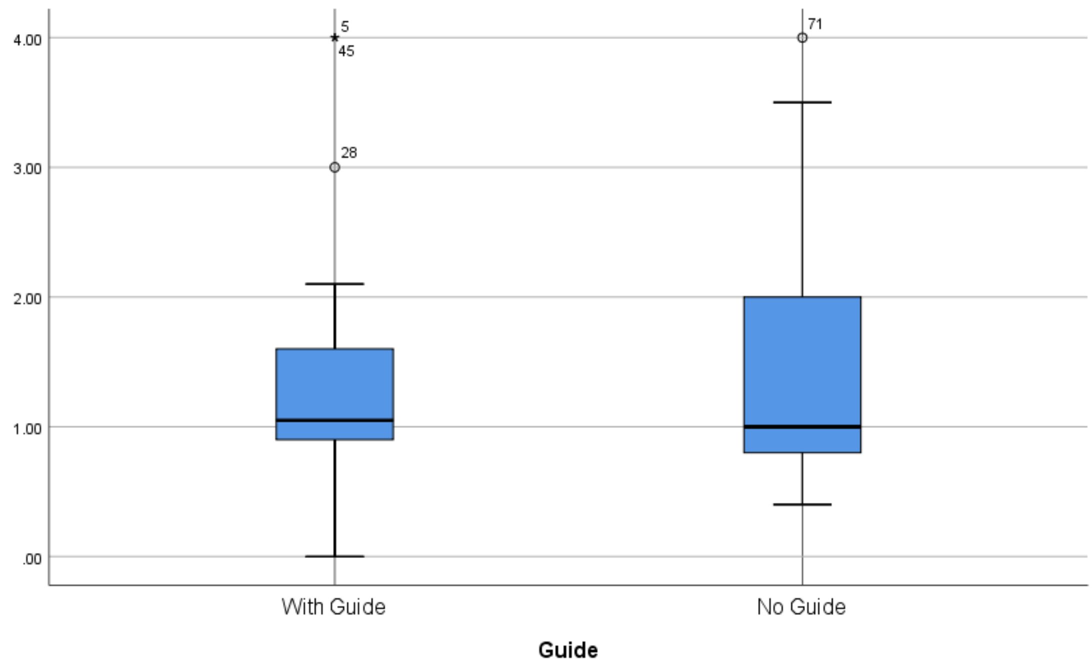

Figure 5. Boxplot of temperature change in guide and no guide groups

Table 1: Mean and standard deviation, mean difference, 95% confidence interval and p-value of the difference between guide and no guide groups

Group	N	Mean (SD)	Mean Difference (SE)	95% Confidence Interval	p
Guide	50	-1.27 (0.75)	0.10 (0.16)	-0.42 – 0.22	0.55
No Guide	50	-1.37 (0.85)			

Table 2: Mean and standard deviation of temperature change in bone blocks used

Bone	Group	N	Mean (SD)
1.00	G	18	-1.31 (0.78)
2.00	G	20	-1.27 (0.58)
3.00	G	12	-1.21 (0.99)
4.00	NG	22	-1.40 (0.90)
5.00	NG	19	-1.22 (0.65)
6.00	NG	9	-1.61 (1.14)

Table 3: ANOVA analysis for temperature difference between the bones

ANOVA

Temp_Change

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.290	5	.258	.385	.858
Within Groups	62.938	94	.670		
Total	64.228	99			

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