

# The Influence of Implant Site Preparation and Sterilization on the Performance and Wear of Implant Drills

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**Purpose:** The aim of this study was to investigate if repeated use of pilot and depth drills for implant site preparation in combination with resterilization leads to any significant changes in cutting edges or in preparation times. **Materials and Methods:** With drills of different lengths and widths (pilot, parallel, and tapered), osteotomies were performed under constant conditions in pig jaws. After each osteotomy, the drills were processed and sterilized. The required time for finishing the osteotomy was noted and analyzed. At the end of each osteotomy cycle, consisting of 10 osteotomies and 10 sterilizations, the cutting edge wear of the drill was analyzed using scanning electron microscopy. Unused but sterilized drills served as a control group. **Results:** There was no statistically significant difference in the evaluated wear between pilot drills and depth drills as well as between the test and the control group. After 60 osteotomies, implant drills showed considerable signs of wear at the major cutting edge ( $P > .05$ ). Osteotomy led to a significant increase in the drilling time. While pilot drills showed an increase of drilling time of the factor 33.3, and the tapered drills of the factor 5.37, the parallel drills remained constant in their performance. **Conclusion:** Within the limitations of this study, it can be concluded that the process of sterilization as well as the number of performed osteotomies play a major role in the wear of the cutting edge and the performance of implant drills. *Int J Oral Maxillofac Implants* 2021;36:546–552. doi: 10.11607/jomi.8099

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Brånamark et al noted the significance of tissue preserving implant site preparation, placing a particular focus on avoiding pathologic temperature rise.<sup>1</sup> Further studies confirmed the harmful influence of heat on osseointegration.<sup>2–4</sup> A series of animal experiments conducted by Eriksson and Albrektsson showed that the temperature rising to 47°C in bone tissue for even 1 minute can lead to irreversible damage to tissue structures as well as to bone necrosis, and can impede osseointegration.<sup>5,6</sup> Various factors that have an influence on heat development in the bone during implant site preparation are currently discussed in the medical literature.

The relevant literature indicates an average contact pressure in implant site preparation between 12 and 20 N.<sup>7,8</sup> Matthews and Hirsch found that axial pressure plays a far more important part in heat generation than drilling speed and came to the conclusion that lower pressure leads to greater temperature rise.<sup>9</sup> When examining the influence of contact pressure and drilling speed, Brisman was able to observe traumatic thermal change at 51.61°C in cortical bovine bone at a drilling speed of 1,800 rpm and contact pressure of 24 N.<sup>10</sup>

Then, a linear correlation between drilling speed and temperature increase was identified by several studies for drilling speeds of up to 2,900 rpm.<sup>9,11,12</sup> Based on similar observations, Eriksson and Albrektsson recommended a rotational speed range of between 1,000 and 2,000 rpm for bone drilling.<sup>6</sup> Conversely, the literature shows that drilling at an increased rotational speed minimizes damage to the surrounding bone tissue. This negative correlation can be explained by the smaller amount of time required, and thus, less total drilling friction in the preparation of the implant site.<sup>3</sup>

Furthermore, drilling without irrigation causes a higher temperature rise than drilling with irrigation.<sup>9,13</sup> In implant site preparation, internal or combined cooling is superior to external cooling, especially when

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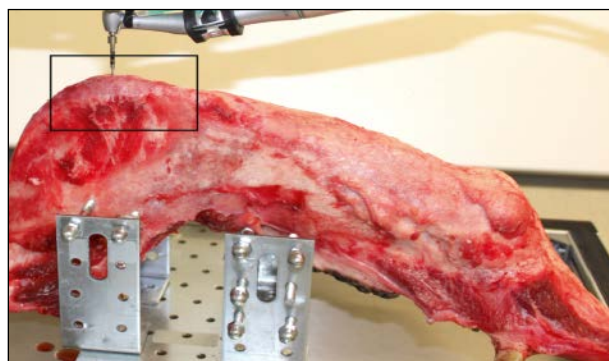
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**Fig 1** Drills used in the study.



**Fig 2** Appliance used in implant site preparation.

drilling to a depth of 16 mm or when a guided osteotomy is used.<sup>14,15</sup>

Regarding the drills used, they differ in terms of the number and geometry of their cutting edges. As a rule, double-edged twist drills provide greater cutting efficiency than three-edged twist drills, but at the same time generate more heat in the bone.<sup>8,13</sup> Additional cutting edges involve the danger of reducing or narrowing the cutting faces, the function of which is to remove the drilling chips; an effective removal of bone chips is thus impeded.<sup>16</sup> Apart from drill design, the type of material and its hardness affect the sharpness of the drill and thus heat generation.<sup>2</sup>

A study by Yacker and Klein proved that bone structure plays an important role as a heat-influencing factor in implant site preparation.<sup>17</sup> Drilling in bovine bones produced a higher temperature as soon as the drill hit compact bone. In cancellous bone structure, a temperature decrease was observed as drilling depth increased. Based on this finding, the authors ascribe far greater importance to bone density in implant site preparation than to drilling depth when it comes to heat generation.<sup>17</sup>

The sharpness of the twist drill is an important factor in tissue-preserving osteotomy.<sup>2,8,9</sup> Heat generation can be reduced considerably if a sharp drill is used at low speed.<sup>18</sup>

The frequency of drilling and autoclave treatment have an influence on drill sharpness and consequently on heat generation during drilling.<sup>19</sup> The findings of further studies also indicated that the cutting efficiency of implant drills is reduced by repeated drilling and disinfection, which also increases the risk of causing thermal damage to the bone tissue.<sup>2,20</sup> In these studies, drill wear was measured based on cutting efficiency in relation to volume wear over time, or the pressure (N) and torque necessary to reach a certain drilling depth. However, direct quantitative observations regarding changes in cutting edge geometry are not available.

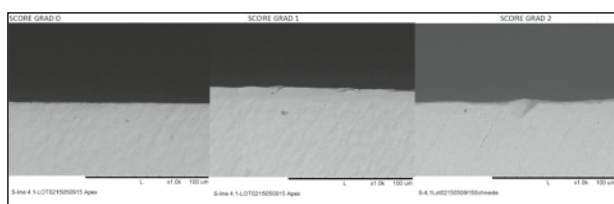
The aim of this study was to determine the wear performance of different implant drills after repeated in vitro use by means of scanning electron microscopy (SEM) and to document and compare their influence on the time of osteotomy. The working hypothesis of the present study was that repeated use of pilot and depth drills for implant site preparation in combination with resterilization does not lead to any significant changes in cutting edges nor in preparation times on a pig jawbone.

## MATERIALS AND METHODS

Table 1 lists the drills selected for the study. Initial cutting was performed with a 2.5-mm pilot drill. The osteotomy was then enlarged with a 4.1-mm drill. All drills were double-edged, stainless steel drills containing 75% iron and 25% aluminum (Fig 1). The same surgical unit (W&H Elcomed 100 Surgical Console System, Nobel Biocare) was used for all osteotomies. The free-running rotational speed of the drills was set at 800 rpm; the torque was set at 50 Ncm. Physiologic solution (external irrigation) was automatically provided by the unit, directed to the drill, and maintained constant at 200 mL/min.

In a preliminary test, the contact pressure necessary for the implant drills was determined. For this purpose, 11 different dentists performed osteotomies in pig jaws using a pilot drill. During drilling, the average contact pressure was determined with the help of a pressure plate. The identified mean value of the contact pressure used was 20 N. As it was assumed that cutting performance decreases in the course of operation, the mean value calculated from the 11 individual values was increased by 10% and established as contact pressure, namely, a pressure of 2.2 kg or 22 N.

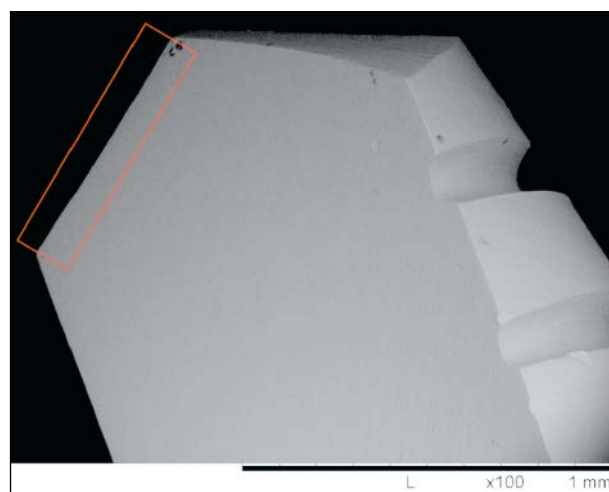
A customized appliance was designed and set up allowing drilling in pig jaws under constant conditions. A contra-angle surgical handpiece with a transmission of 20:1 (WI-75 E/KM, W&H) was fixed to a guide rail and loaded with a weight of 2.2 kg (Fig 2).



**Fig 3** Examples of wear grades 0, 1, and 2 according to SEM images.

**Table 1** Implant Drill Specifications and Irrigation Design

Drill	Bit (w × l)	Design	Irrigation
Pilot	2.5 × 15 mm	Cylindric/twist	External
Tapered	4.0 × 15 mm	Conical/twist	External
Parallel	3.65 × 15 mm	Cylindric/twist	External



**Fig 4** SEM wear: examination of a pilot implant drill.

Drilling was performed on the jawbones of organic pigs. On the evening before the experimental procedure, the pig jaws were slowly thawed at room temperature. Before drilling, the pig jaw is always kept moist in a water bath at room temperature to avoid dehydration. Before implant site preparation, bone quality was classified according to Lekholm and Zarb through bone density measurement in a CBCT scanner.

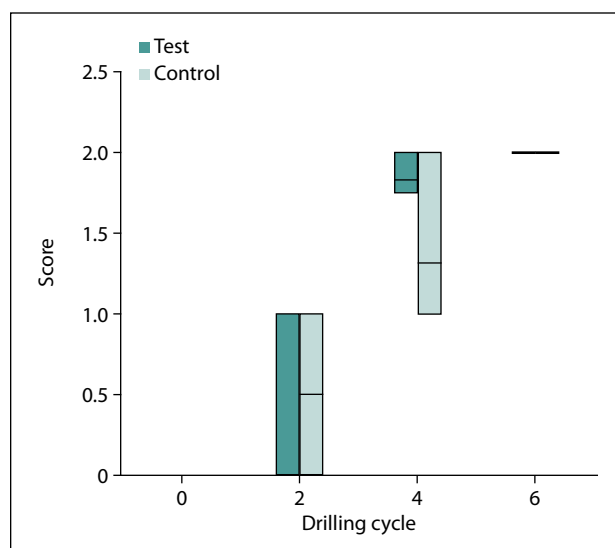
The surrounding tissue and periosteum were removed from the pig jawbones in the drilling area using a surgical blade and a periosteal elevator in order to ensure proper removal of chips during the drilling procedure. Drilling in pig jaws was performed in the area of the mandibular angle, as shown in Fig 2. Before drilling, the pig jaw was fixed, and the guide rail construction was moved until the twist drill touched the bone.

The time for drilling was determined by inductive proximity sensors. The detection frequency of the sensors used was 500 Hz (0.002 seconds). The sensors were placed at a distance of 13 mm, the desired drilling depth. The sensors for time measurement were adjusted in such a way that recording started simultaneously with the beginning of drilling and ended after a drilling depth of 13 mm was reached. If the drilling depth of 13 mm was not reached within 120 seconds, the drilling procedure was stopped and counted as a failed attempt. After each drilling procedure, all bone chips were carefully removed from the drill using water and a nylon brush.

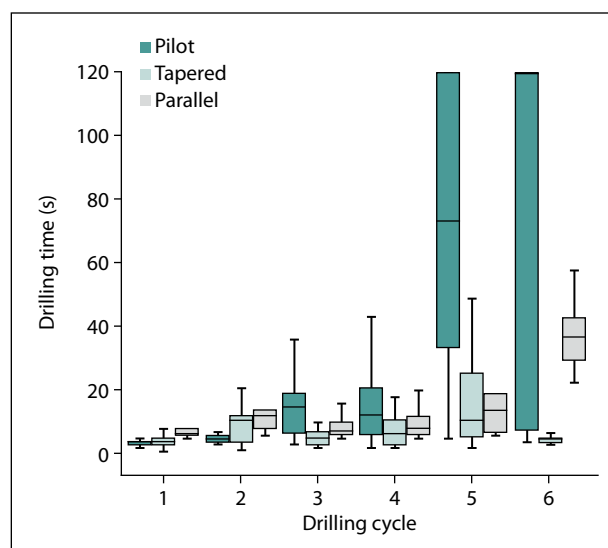
Each drilling cycle, which comprised 10 drilling procedures, was followed by a sterilization cycle, which accordingly consisted of 10 sterilization procedures. According to the manufacturer's manual, the sterilization procedure included mechanical cleaning and disinfection in an ultrasound bath (Elmasonic S 130H, Elma Schmidbauer) as well as vacuum autoclave sterilization (Vacuklav 40 B+, Melag). For the present study, the drills were cleaned and disinfected separately to avoid having contact with each other. Contact with each other could result in wear of implant drills and falsify the results. For the control group, the implant drills underwent only the sterilization procedures.

After 20 drilling and corresponding sterilization procedures, the drills of both groups were examined by means of SEM (TM-1000, Hitachi) under 1,000× magnification. The outcome was compared with the situation at the beginning before the first drilling procedure, and a qualitative assessment was done regarding geometry and deformation. A score of three grades was used to quantify the deviation between the pictures taken before the first use and the situation after use (Fig 3):

- Grade 0: No change with respect to initial condition
- Grade 1: Visible changes, straight cutting line, no chipping
- Grade 2: Visible changes, cutting line with chipping



**Fig 5** Determined wear score after every second drill cycle.



**Fig 6** Mean values of the measured drilling times of six drilling cycles: pilot, tapered, and parallel drills.

Figure 4 displays an SEM image of the investigated area of a pilot drill marked in a red frame.

Statistical evaluation was performed with SPSS for Windows, Release 17.1 (SPSS). Normal distribution of the data was determined by the Shapiro-Wilk test. The Mann-Whitney *U* test and the Brown-Forsythe test were used to compare the mean values of the drill wear scores. The differences between the groups regarding drilling times were calculated on the basis of the Kruskal-Wallis and Tukey tests. The level of significance was set at .05.

## RESULTS

The scores determined for the tested drills in the test group and in the control group are summarized in Fig 5.

In the test group, the Tukey test showed no significant difference in the wear scores after 20 cycles compared with the initial situation. Only after the second drilling and sterilization cycle, a statistically significant change in the condition of the main cutting edge was observed. In contrast, a significant change occurred in the control group only after 60 sterilization cycles.

There was no statistically significant difference in the evaluated wear between pilot drills and twist drills and between the test and control groups.

The mean values of the measured drilling times of six drilling cycles (each one consisting of 10 drillings and

sterilizations, respectively), performed with different drill designs, are shown in Fig 6.

In the pilot drill group, a significant increase of drill times was noted after three cycles. After four drilling and sterilization cycles, more than one-third of drilling procedures were unable to reach the desired depth within 120 seconds under test conditions; after five cycles, none reached the desired depth.

While the parallel-depth drills displayed a significant increase in measured drilling times for the fifth drilling cycle, they did not significantly differ in the next cycle compared with the initially measured values. The longest drilling time was 49 seconds.

For the tapered-depth drills, a statistically significant increase in drilling times was observed after 40 and 50 drilling and sterilization cycles, respectively, with a measured maximum drilling time of 72 seconds.

## DISCUSSION

In this experimental study, multiple implant site preparations followed by steam sterilization were performed in pig jaws using drills of different diameters and geometries. Drilling times were measured, statistically evaluated, and compared in pairs. Visual assessment of signs of wear on the main cutting edge was based on SEM at 1,000× magnification and on a defined scoring system.

Reusable implant drills are usually designed for 10 surgical procedures. A study conducted by Medical Data International in the United States showed that the average number of implants inserted per surgical procedure is 2.5. This means that a reusable implant drill has to maintain its surface condition and cutting efficiency for at least 25 tissue-preserving osteotomies.<sup>21</sup> Under study conditions, the implant drills used showed a significant deterioration of the cutting edge geometry and increase of drilling time only after 40 drillings and sterilizations.

A pig's lower jawbone was used as a bone substitute. This bone in particular and pig bones in general have been described as well suited as a bone substitute because their cortical and cancellous structure is similar to the human structure with comparable mechanical properties.<sup>13,19,22</sup> In both pig and human jaws, regions of high (D1 and D2) and lower (D3 and D4) density were found.<sup>18</sup> Differences in bone quality concerning the ratio of cortical to cancellous bones in the drilling area were regarded as a natural variance, as they occur in pig jaws as much as in the jaw of any other creature. In the present study, the bone density of the specimens was measured using a CBCT scanner. In order to classify the bone quality of the specimens according to Lekholm and Zarb, determining cortical thickness is crucial.<sup>23</sup> Suttapreyasri et al investigated the accuracy of CBCT for evaluating bone density and cortical bone thickness at the implant site compared with micro-CT and histologic analysis.<sup>24</sup> It was concluded that using CBCT for determining cortical thickness is highly accurate, and a correlation was identified between cortical thickness measured from the CBCT and micro-CT.

Axial drilling pressure was kept constant at 22 N, as established following a preliminary test with 11 dentists. The literature identifies the axial pressure acting on the contra-angle surgical handpiece as a heat-influencing factor; however, statements regarding a suitable value differ. Values range from nonspecific recommendations of low contact pressure and values of 12 N to contact pressures of 20 N or 24 N.<sup>7,8,10,25</sup>

Drilling procedures with both the pilot drill and the depth drill were performed at a drilling speed of 800 rpm. This rotational speed corresponds to the manufacturer's recommendation and also lies within the rotations per minute range postulated by many authors.<sup>6,11,12,26,27</sup>

The ratio of drilling cycles to sterilization cycles represents another important factor of drill wear. Jochum and Reichart showed that only drills that underwent autoclave treatment develop a larger cutting edge angle.<sup>19</sup> With an eye to the effect of autoclave treatment on cutting efficiency, a ratio of 1 to 1 was established for the relation between implant site preparations and sterilization cycles. Despite the fact that several

implants were frequently inserted per surgical procedure, this ratio is, in the authors' opinion, relevant to everyday practice.

In preliminary tests on the same animal model, it could be observed that no further penetration of the drill was to be expected after 120 seconds. From 120 seconds on, the drill rotates on the spot. This was why a time limit for osteotomy was set at 120 seconds.

In this study, the cutting efficiency of the implant drills was defined by the time needed to complete an implant site preparation of 13 mm. While for the pilot drills, the drilling time increased by factor 33.3 (mean times 3.6 seconds after one drilling cycle and 120 seconds after six drilling cycles), for the tapered depth drills, this value was 5.4 (6.9 seconds/37 seconds, respectively). For the parallel-depth drills, virtually no significant difference in drilling times could be detected (6.9 seconds/37 seconds, respectively). For the pilot drills, the high impact of the drilling cycles on cutting efficiency can be explained by the fact that they have to penetrate the intact cortex leading to a higher loading in the apical drill region. For both drills used, the pressure on the handpiece was the same, meaning that the force per length ratio differed. As the tapered-depth drill is conical, the length of the cutting flute is smaller compared with the length of the cylindrical cutting flute of the parallel-depth drill. This might result in the differences in wear and variations in the cutting flute.

The wear patterns obtained by the SEM examination and defined by the score are statistically not significantly different in the pilot drill and the depth drill and in the experimental and control groups. Thus, the sterilization process might play an essential role in the wear of the main cutting edges.

Every sterilization process results in thermal, pressure, and mechanical loading for every drill. This leads to wearing effects on the cutting flute. For the pilot drills, significant differences in the drilling times could be observed only between cycles 4 and 5. An increase in mean values from 15.3 to 71 seconds with more than one-third of the drills without success after 120 seconds let the question arise as to what extent tissue preserving or even an osteotomy with drills reused more than 40 times is still possible. From a practical point of view, to meet the recommended rotation speed of 800 rpm, only the axial pressure load could be increased. Increasing this parameter could reduce the time required for the preparation or allow penetration of the compact bone in the first place but would result in an increase in temperature.<sup>10</sup> It could be concluded that the pilot drills should not be reused more than 20 times.

Although for the parallel-depth drills, a post hoc test showed statistical differences between cycles, no clear tendency for osteotomy time increase could be



detected (Fig 6). All drilling times were within a time frame of approximately 4 to 11 seconds; in clinical terms, a noninvasive atraumatic osteotomy could be ensured.<sup>26</sup> These deviations in the measured drilling times could be explained by the biologic variance of the pig jaw.<sup>18</sup> However, in order to obtain clear results with regard to these drills, a synthetic bone substitute with a higher grade of homogeneity might be more useful.

For the tapered-depth drills, there was a statistically significant increase in drill times between the fifth (13,306) and the sixth (36,973) cycles. In the group, the calculated mean values were higher than the parallel-depth drills and ranged from 7 to 37 seconds. The clinical relevance of this significant increase in drilling time must be taken into account. According to Sutter et al, even after an observation period of 80 seconds and sufficient cooling, the traumatic thermal temperature of 47°C defined by Eriksson and Albrektsson would not be reached.<sup>6,26</sup> Whether and to what extent these data can be transferred to this experimental study is nevertheless open due to different parameters and requires further investigation.

For the SEM examination of the drill wear, a control group was introduced in addition to the experimental group in order to evaluate the influence of the drilling or the sterilization process. While there was a statistically significant difference in the experimental group from the initial situation after the second drilling and sterilization cycle ( $P = .045$ ), this was recognizable in the control group after the third cycle ( $P = .015$ ). Moreover, when comparing the individual cycles of the experimental and control groups, no statistically significant difference was observed at any time. Consequently, it could be concluded that irrespective of whether implant drills were applied with the drills, the signs of wear on the main cutting edge could be deduced from the sterilization process. This result coincides with other experimental findings of Jochum and Reichart.<sup>19</sup> Contrary to the temporal evaluation of both drill types, the results of the Mann-Whitney and Brown-Forsythe test ( $P = .092$  and  $P = .699$ ) showed that there is no statistically significant difference in the wear behavior between pilot and depth drills.

The results and conclusions here are based on implant drills from one manufacturer.

Manufacturer variability depending upon the type of material, alloy, and the form of drilling pressure application (consistent vs intermittent pressure) could be expected.

An important goal of this study was to design and set up a device to simulate implant osteotomy under controlled conditions. From this point of view, the present study is considered to be a pilot study. Further investigations are planned on the basis of this study design.

## CONCLUSIONS

Within the limitations of this study, the following can be concluded: (1) implant drill geometry significantly affects cutting efficiency and durability; (2) implant drills can be used several times without losing cutting efficiency; (3) tapered-depth drills seem to have a higher wear resistance compared with parallel-depth drills; and (4) the sterilization process might play an essential role in the wear of the main cutting edges. Further investigations with a broad range of manufacturers are necessary for a better understanding of the influence of implant site preparation and sterilization on the performance and wear of implant drills.

## ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

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