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Evaluation of bone removal during osteotomy for implant placement using standard surgical drills made of three different materials - A comparative in-vitro study

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Abstract

Aim: The purpose of the current study is to assess and compare the bone removal in osteotomy site preparation for implant placement using surgical drills made of three different materials.

Materials & Methods: 180 osteotomies were prepared on the lower border of thirty goat hemimandibles. Three implant surgical drill materials were used and grouped as Group A – Diamond-like carbon drills (Adin – Israel), Group B – Titanium drills (Nobel Biocare – Germany), Group C - Stainless steel drills (Norris – Israel). Sixty osteotomy sites are prepared with each group, six per goat hemimandible at the equidistant position. The amount of bone removal was measured at every 3 mm from the crest level at crestal third, middle third, and lower third by using On-Demand software in Cone-beam computed tomography.

Statistical analysis: One-way analyses of variance was done to analyze the study data.

Results: There was no significant difference evident statistically for the amount of bone removal at crestal third (mean bone removal of 3.203 mm for all three materials) whereas there is a statistically significant difference in bone marrow loss at the middle third and lower third with the stainless-steel implant drills (P 0.007) than with the titanium and diamond-like carbon surgical implant drills.

Conclusion: Within the limitations of the study, amount of bone removal with the three materials was well within at the crestal third, comparatively greater bone removal is evident with stainless steel at the middle and lower third respectively.

Keywords: Diamond-like carbon, Titanium, Stainless Steel, Bone removal, Cone-beam computed tomography.

Introduction

Dental implants are a popular alternative in oral rehabilitation with the introduction of osseointegration by Brånemark.[1] Osseointegration is the initial step for the success of the treatment. Surgical trauma to bone tissue can be minimized during osteotomy as a controllable factor that affects osseointegration.[2] Precise osteotomy site preparation and choice of corresponding drilling tools and implant systems is very essential. [3] The osteotomy site for implant placement is mandatory for the successful and long-term success of implants. Drills should be used in such a way that excellent primary stability is achieved. [4]

Implant drills are made of different materials, such as SS, zirconia, titanium, diamond-like carbon, ceramic. Diamond-like carbon (DLC) was added as a drill coating because of its tribological properties like low friction coefficients, increased hardness, wear resistance, durability, and biocompatibility. Recently, titanium coatings are widely used as protective coatings due to their good mechanical properties such as hardness, durability, low friction, corrosion resistance, and high-temperature-induced oxidation. [5]Stainless steel drills have improved properties such as stability, thermal conductivity, resistance, and wear, which can influence the temperature during osteotomy. [6]

Cone beam computerized tomography is the most accepted method in the objective evaluation of bone, providing three-dimensional views, cross-sectional views, and bone density values. It analyzes the morphologic as well as qualitative characteristics of bone.[7]

The current in vitro experimental study on animal models aims to evaluate the quantity of bone removed with diamond-like carbon, titanium, and stainless-steel drills standard drills when used for creating the implant osteotomy for placement of dental implants using cone-beam computed tomography (CBCT).

The null hypothesis was that the amount of bone removal during osteotomy will be similar between diamond-like carbon, titanium, and stainless-steel drills.

Materials and Methodology

A total of 180 osteotomy sites in 30 fresh goat hemimandibles were prepared. Goats slaughtered at the local butcher's shop for human consumption were used in the study.

Ethical Committee clearance was obtained from the Institutional Ethics Committee for the use of goat mandible in the study. Freshly removed goat mandibles were cleaned to remove blood, soft tissue, and debris. Osteotomy sites are prepared within 1 hour after removal.

The 180 osteotomy sites are divided into three equal groups (60 each). The sample is divided based on the implant surgical drill material used.

Osteotomy in the goat Hemi mandible of group A was prepared with Diamond-like carbon surgical drills, group B with titanium surgical drills, and group C with stainless steel surgical drills till 3.2mm width and 10mm length. Goat mandibles are mounted in a dental stone base of length 11 cm, the width of 7 cm, and the height of 2.5 cm using the plastic mold.

Osteotomy site preparation procedure

The physio dispenser (NSK physio dispenser) for osteotomy site preparation is programmed with a speed of 800 rpm in the forward direction, 50 Ncm of torque, and saline coolant. Osteotomy site preparation was started with a pilot drill.

Then the sequential drilling was done till 3.2mm diameter with a depth of 10mm. Six osteotomy sites were prepared on each goat mandible using a dental implant micro motor cord handpiece connected to a physio dispenser with copious saline irrigation parallel to each other (Figure 1).

Each goat mandible consists of two osteotomy site preparations with diamond-like carbon drills, 2 osteotomy site preparations with titanium drills, and 2 osteotomy site preparations with stainless-steel drills from anterior to posterior direction (Figure 2). Parallelism is evaluated using parallel pins. Each group consists of 60 osteotomy sites with a total of 180 osteotomy site preparations.

Samples were then subjected to cone-beam computed tomography and analysis of the amount of bone removal was done.

Figure 1: Osteotomy site preparation.

Figure 2: Osteotomy sites on the lower border of mandible

Cone-beam computed tomography imaging & evaluation

The base of the dental stone block was secured at the Center and the samples were subjected to x rays on a standard platform.

The cone-beam computed tomography image was then captured into the desktop computer and is evaluated using on-demand 3D software.

The linear distance of bone removal in the osteotomy site is evaluated at the crestal third, middle third, and the lower third at every 3mm (Figure 7A, 7B, 7C).

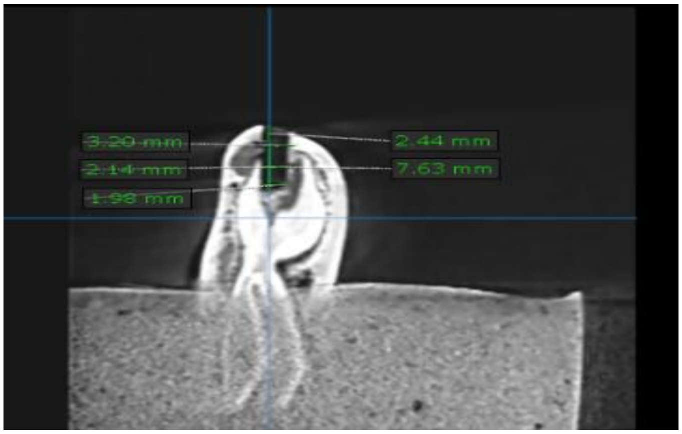


Figure 2A

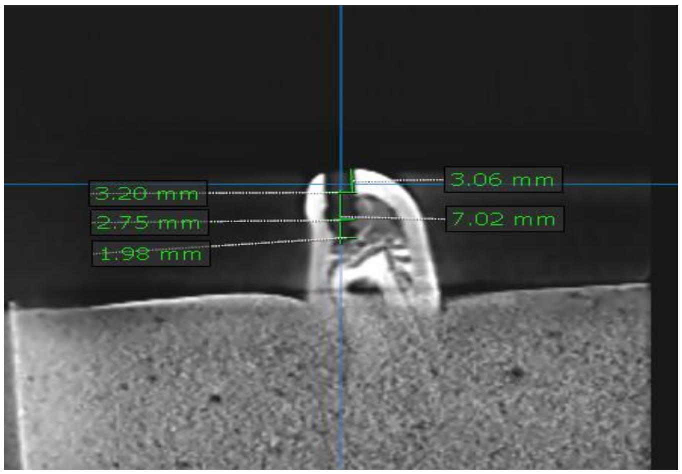


Figure 2B

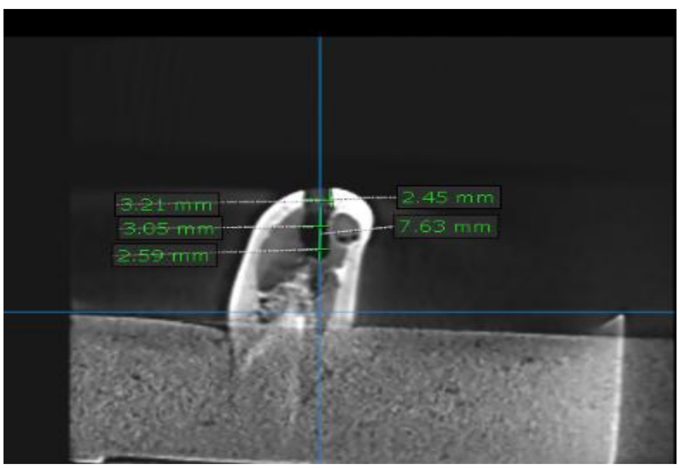


Fig 2C: CLinear distance measurement at crestal third,middle third, and lower third with 2A) DLC drills; 2B) Titanium drills; 2C) Stainless steel drills in cross-section

Results

Data were analyzed using SPSS version 20 software (IBM SPSS, IBM, Armonk, NY, USA). Descriptive statistics, One-way analyses of variance is done to analyze the study data. Table 1 presents the comparison of study parameters between the groups showing no significant differences (P 0.817) between the materials with regard to crestal bone removal and statistically significant difference in bone marrow removal at middle third between the groups with stainless steel surgical implant drills(2.73±0.26mm) demonstrating comparatively greater bone removal than the titanium (2.61±0.31mm) and diamond-like carbon surgical implant drills(2.59±0.29mm). Similar observations were noted with regard to bone marrow removal at the lower third (Graph 1).

Table 1: Comparison of study parameters between the groups with One-way analysis of variance.

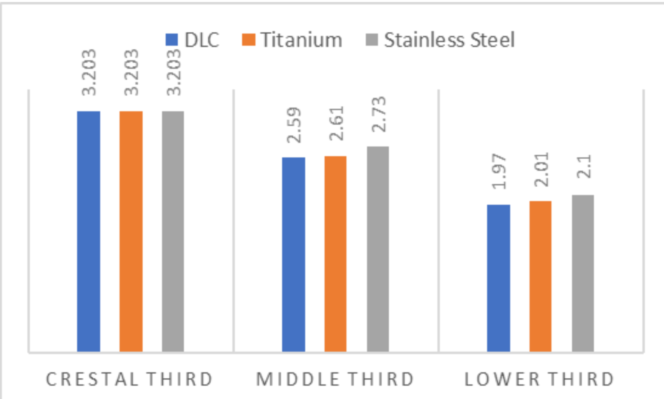
Variable	Group	Mean±SD	F value	P-value
Crestal third	DLC	3.203±0.005	0.203	0.817
	Ti	3.203±0.004		
	SS	3.203±0.004		
Middle third	DLC	2.59±0.29	4.001	0.02*
	Ti	2.61±0.31		
	SS	2.73±0.26		
Lower third	DLC	1.97±0.36	5.12	0.007*
	Ti	2.01±0.28		
	SS	2.1±0.38		

*P<0.05, DLC: Diamond-like carbon, Ti: Titanium, SS: Stainless steel, SD: Standard Deviation

Discussion

Until recent times, standard surgical drilling is the most followed osteotomy preparation technique for implant placement.[8] Bone preservation and maintaining the bone histologically during the preparation of the osteotomy is important for success of the endosseous implant.[9] The protocol for the rehabilitation with implant-supported prosthesis requires minimal surgical intervention.[10] Conservative bone removal during the implant osteotomy offers adequate mechanical stability for the dental implants which in turn offers higher rates of osseointegration.[11]

Graph 1: Comparison of study parameters between the groups



DLC: Diamond-like carbon

The osteotomy site preparation technique involves the cutting and extraction of bone tissue to create a cylindrical osteotomy that will receive an implant fixture.[12] Usually, the preparation of an implant site consists of the use of a series of drills, each of increasing diameter.[13] Geometrical accuracy of osteotomy site and size is necessary for rigid fixation.[14]

Drill wear is one of the factors in heat generation during osteotomy site preparation.[15] The implant drills are designed with consideration of various factors, such as cutting efficiency, strength, vibration, and bone chip formation.[16]Nilay Er demonstrated that diamond-like carbon-coated dental implant drills displayed an approximately 20% improvement in performance and durability compared with stainless steel drills.[5]Bullion found that precipitation-hardening stainless steel presents better mechanical properties and corrosion resistance than martensitic stainless steel.[17]Titanium has become a standard material for dental implants as well as for surgical drills.[18]

Different drill designs and geometries have been suggested for years each with their claim to success, but most of them are based on conventional drill geometry. [19] Studies have found that maximum cortical bone temperatures are directly related to drilling force.[20] Apart from the increase in temperature, osteotomy site preparation also influences bone healing. After the osteotomy site, preparation, and placement of dental implants a sequence of cellular and molecular events are initiated which represents a combined response of wound healing.[19] One of the factors critical for dental implant osseointegration is the avoidance of thermally induced necrosis at the osteotomy site. [21]

CBCT was used for imaging in this study owing to its reliability in being applied in different clinical situations where linear measurements between anatomical sites are required.[22] Studies have shown the accuracy of cone-beam CT images high for linear measurements.[23]

TK Pal et al found a similarity of micro-anatomical dimensions between goat and human mandibles stating goat mandible is suitable for many implant experiments.[24] Thereby, goat mandibles are of choice to study the quantitative bone removal at different levels of osteotomy preparation. Parallel placement of dental implants is an accepted surgical and prosthodontic norm when multiple implants are considered. The use of paralleling pins is an arbitrary method to evaluate the parallelism between implants intraorally.[25]

In the present study amount of bone removal is determined as maximum linear distance (outer line of cortical bone) on a coronal section at each osteotomy site of the CBCT scan. The most distal point and mesial point of the osteotomy site are taken as a limit to measure. The linear distance of bone removal is recorded in millimetres. From the initial line, consecutive linear distances for every 3mm interval are measured. The measurements are made for six osteotomy sites on each goat mandible, respectively for three groups.

The amount of bone removal at crestal third of group A was compared to group B and similarly, with group C.The crestal bone removal has a mean of 3.203±0.005 mm in group A, 3.203±0.004 mm in group B, and 3.203±0.004 mm in group C respectively. According to one-way analyses of variance, and Tukey's post hoc tests there was no statistically significant difference found at the crestal third. The amount of bone removal at the middle third of group A was compared to group B and similarly, with group C. The bone marrow removal at the middle third has a mean of 2.59±0.29 mm in group A, 2.61±0.31 mm in group B, and 2.73±0.26mm in group C respectively.

There was a statistically significant difference in bone marrow loss at the middle third with the stainless-steel surgical implant drills(P 0.02) demonstrating comparatively greater bone loss than the titanium and diamond-like carbon surgical implant drills.

The amount of bone removal at the lower third of group A was compared to group B and similarly, with group C. The bone marrow removal at the lower third has a mean of 1.97±0.36 group A, 2.01±0.28 mm in group B, and 2.1±0.38 mm in group C respectively. There was a statistically significant difference in bone marrow loss at the lower third with the stainless-steel surgical implant drills (P 0.007)) demonstrating comparatively greater bone loss than the titanium and diamond-like carbon surgical implant drills. Studies by Thompson and Natalia Oliveira werein consideration with the present study.[26,27] Darpan Bhargava et al. found bone loss at cortical and bone marrow levels with the standard drill than trephine and alveolar expander.[28] Higher temperatures with stainless steel drill and carbide drill, when compared with the diamond-coated drill, are recorded in the studies.[29] The present study reinforces the idea that implant surgical drill material affects the amount of bone removal which may be attributed to geomorphometric, thermographic, and radiographic effects of implant drill on osteotomy site preparation.

This study evaluated and compared the amount of bone removal in preparation of osteotomy site with DLC, Titanium, and stainless-steel implant drills respectively. All three materials showed equal bone removal at the crestal level whereas stainless steel showed comparatively more bone removal in the lower and middle third of the osteotomy site.

The limitation of the present study was in vitro animal model assessment which does not simulate the exact oral conditions of the human. Future studies need to assess the criteria in vivo, the effect of drill wear & heat generation of different commercially available implant drills, and their effect on the amount of bone removal and osseointegration.

Conclusion

Within the limitations of this in vitro study, the following conclusions can be drawn

- There was a statistically significant difference between the three materials tested.
- According to the statistical analysis there was no significant difference in the bone removal at crestal third between DLC, titanium, and stainless steel.
- There was significant bone removal at the middle and lower third with the stainless-steel drill in osteotomy site preparation.

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