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Analysis of Influence and Composition of the Metal Alloys of Two Implant Drill System

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Abstract

The mechanical behavior of two different implant drill systems for osteotomy preparation using polyurethane foam models were evaluated.Methods: Fourteen polyurethane foam models and 28 Neodent® drills and 28 Dentoflex® drills were used. In a controlled environment, the perforations were timed, and an infrared digital thermometer and a K-type sensor were used to measure the temperature before and after perforations. Each group was divided into 7 subgroups: S5 = 5 perforations, S10 = 10 perforations, S15 = 15 perforations, S20 = 20 perforations, S30 = 30 perforations, S40 = 40 perforations, and S50 = 50 perforations.Results: In the S5 and S10 subgroup, drilling time of the drills with three helical cutting edges was longer ($p < 0.05$) and temperature 1 was lower ($p = 0.034$) in the S10 group.

Index terms— biomechanics; dental implantation; mechanical stress; osteotomy.

1 Introduction

he number of patients in need of prosthetic rehabilitation with dental implants has been increasing significantly due to the increase in life expectancy associated with the search for better esthetics and functional results. Simpler and more effective osteotomy for the placement of implants has been a major challenge for oral surgeons. 1 Transoperative management is challenging due to surgical trauma and the biotype of periodontium influences the esthetic outcome. In vivo and in vitro studies have shown that osseointegration, which may lead to failure of dental implants, cutting speed, pressure exerted at the time of instrumentation, drilling time, quality and drill design, external and internal irrigation, material used to manufacture drills, the surgical process and bone morphology all influence the outcome of implantation. 2,3 Other authors also mention that cleaning and sterilization of surgical drills are a determining factor in instrument wear, which would lead to loss of efficiency, thus directly compromising final osseointegration. 4 The currently used clinical protocol for osteotomy for the placement of implants is the gradual increase in the diameter of the surgical drills to a diameter compatible with the external diameter of the implant thread. 5 Bone perforation for the placement of implants results in heating due to friction and fragmentation of bone particles on the cutting surface of the drill, 6 and peripheral thermal bone necrosis may occur due to inadequate cooling or loss of the cutting efficiency during the preparation of the alveoli. 7 The evolution of materials used in implantology has led to the development of new types of drills. Surface treatments and new metal alloys have been used to improve physical properties for greater efficiency and durability. 8 The most widely used metal alloy in medical and dental instruments for surgical procedures is martensitic stainless steel, which contains carbon (to increase hardness), chromium and molybdenum (to improve corrosion resistance). Different drill designs have been introduced for greater bone-cutting efficiency. 9 Thus, the aim of this study was to evaluate in vitro the mechanical behavior of two specific implant drill systems for bone bed preparation after osteotomy using polyurethane foam models.

2 II.

3 Material and Methods

Fourteen polyurethane foam models (Nacional Ossos, Jaú, São Paulo, Brazil) and 56 surgical drills were used in this study and divided into 2 groups: Group N: Neodent® group composed of helical drills made from heat-hardened surgical stainless steel (440C) (Neodent®, Curitiba, Paraná, Brazil); Group D: Dentoflex® group consisting of heat-hardened surgical stainless-steel drills (XM-16) with three helical cutting edges (Figures 1 A and ??). Each experimental group was then divided into 7 subgroups: S5, S10, S15, S20, S30, S40 and S50 that correspond to the quantities of perforations (S5 = 5 perforations, S10 = 10 perforations, S15 = 15 perforations, S20 = 20 T perforations, S30 = 30 perforations, S40 = 40 perforations and S50 = 50 perforations). A total of 170 cavities were made in seven polyurethane foam models for each experimental group. The 30-PCF polyurethane foam models (specimen) simulating a 1-mm thickness type I cortical bone (measuring W 6.0 x L 14.0 x H 3.3 cm) received the number of cavities corresponding to their respective subgroups. The drilling protocol was carried out by the vertical displacement of the contraangle fixed to a bench forming a right angle between the end of the drill and the polyurethane foam model, exerting constant pressure in all the perforations, at a rotation speed of 1400 rpm with constant irrigation (Figure 2). All perforations were evenly distributed at 6mm and standard depth of 11mm. The drilling for the placement of the K-type thermocouple thermometer was carried out using the PROSS electric micromotor (Dabi Atlante®, Ribeirão Preto, São Paulo, Brazil), and a Ø 1.5mm helical drill, at a depth of 11mm from the cortical surface and 1.5 mm in front of the perforation of the experimental groups, previously marked with an endodontic ruler. The milling sequence was the one recommended by the manufacturers (Neodent® and Dentoflex®), as follows: 1-Ø 2.0mm initial drill; 2-Ø 2.0mm helical drill; 3-Ø 2/3 pilot drill and 4-Ø 3.0mm helical drill (Neodent®, Curitiba, Paraná, Brazil), and 1-Ø 2.3 mm drill; 2-Ø 2.6mm helical drill; 3-Ø 2.9mm helical drill and 4-Ø 3.2mm helical drill (Dentoflex®, São Paulo, São Paulo, Brazil). The drill was mounted on the PROSS electric micromotor (Dabi Atlante®, Ribeirão Preto, São Paulo, Brazil) with a contra-angle handpiece (Dabi Atlante®, Ribeirão Preto, São Paulo, Brazil) of 20:1 reduction.

4 a) Analysis of variables i. Time

Cavity preparation time was measured with the aid of a professional digital stopwatch (VL510, Polo Industrial Granja Viana/Cotia -SP-Brazil) with an accuracy of 1/100 seconds. The total milling time was calculated by adding the contact time of each drill on the polyurethane foam model until reaching the depth of 11mm.

5 ii. Temperature

The external thermographic analysis of the cavity preparation was measured immediately before and during milling with the aid of a digital infrared thermometer (Kiray 50, Emerainville, France) fixed to a tripod at a distance of 50cm from the polyurethane foam model (Figure 3). The infrared beam was positioned at the cutting/surface intercession of the model and the highest temperature was recorded in degrees Celsius (ºC). To measure the temperature inside the polyurethane foam model, a K-type digital thermometer (Hibok 14, WikaLda., Taoyuan, Taiwan) was used and readings ranged between -50 to 800°C. The thermocouple probe was calibrated (at 11 mm) against traceable standards (5°C and 55°C) before each perforation. After being placed on the prepared place, it was sealed with blue wax, thus allowing no temperature interference due to irrigation.

6 iii. Statistical analysis

Statistical analysis was performed using the SigmaStat 3.5 software (Systat Software Inc., San Jose, CA, USA). The Shapiro-Wilk and Brown-Forsythe test were applied to all groups to analyze the normal data distribution and equality of variance, respectively. Parametric data were analyzed using the Analysis of Variance test and non-parametric data were submitted to the Kruskal-Wallis test. For post-hoc comparisons, the Student-Newman-Keuls test was used and the level of significance adopted was $p < 0.05$.

7 III.

8 Results

The results of the evaluation of time and temperature variation are described in Table ??. Regarding drilling time, helical drills were statistically faster than drills with three helical cutting edges for all subgroups ($p < 0.05$), except for the 15-perforation subgroup ($p = 0.520$). Regarding temperature variation measured with the K-type digital thermometer (temperature 1), helical drills generated significantly more heat than drills with three helical cutting edges in the 10-perforation subgroups (2.8 ± 1.2 vs 1.6 ± 0 , 5 ºC), 15 (3.3 ± 1.2 vs 0.9 ± 0.4 ºC) and 20 (2.9 ± 1.2 vs 1.5 ± 1.3 ºC) ($p < 0.05$). In 5 (1.5 ± 0.3 vs 1.3 ± 0.4 ºC), 30 (2.7 ± 1.2 vs 2.6 ± 1.9 ºC) and 40-perforation subgroups (2.5 ± 1, 2 vs 3.3 ± 2.3). There was no statistical difference between the groups ($p > 0.05$). On the other hand, drills with three helical cutting edges produced more heat than helical drills when 50 perforations (2.3 ± 1.1 vs 3.6 ± 2.7) were performed ($p < 0.001$).Regarding temperature variation measured by the infrared thermometer (temperature 2), there was no statistical difference between the groups in the 5perforation (0.4 ± 0.3 vs 0.3 ± 0.1 ºC), 10 (0.3 ± 0.3 vs 0.3 ± 0.1 ºC), 20 (0.5 ± 0.3 vs 0.8 ± 1.3 ºC) and 30perforation (0.5 ± 0.3 vc 1.3 ± 1.0 ºC) subgroups ($p > 0.05$). However, when 15 (0.6 ± 0.3 vs 0.2 ± 0.1 ºC) perforations were made, the helical drills generated more heat ($p < 0.001$) and when 50 perforations (0.5 ± 0.3 vs 2.0 ± 1.8 ºC) were made, the drills with three helical cutting edges presented higher temperatures ($p = 0.024$).

9 IV.

10 Discussion

In the present study, the mechanical behavior of two different sets of national implant drills was analyzed, which are specific for implant bed preparation with osteotomies in polyurethane models. We compared drill wear after repeated use and their influence on heat generation and time related to milling. In addition, a comparison was made between the values found. In order to carry out this study, we decided to use synthetic bones (polyurethanes) with densities similar to those found in human bones, since the standardization of specimens and homogeneity of samples, which greatly influence statistical analysis, are achieved. Synthetic bones with mechanical properties similar to natural bones are a promising alternative, as human bones are difficult to store and obtain homogeneity of samples. In addition, there are characteristics that can influence the reliability and validity of measurements, such as unknown fenestration ??10,11 In a study that evaluated the standardization and reproducibility of the homogeneity of polyurethane foam models used as bone substitutes in research, the authors concluded that polyetherane models with densities (per cubic centimeter -DCC) from 30 to 40 were the ones that showed the best results in the tests of compression and bending tests in comparison with others, being, therefore, the most suitable for mechanical tests of implants. 12 Due to these factors, our research used polyurethane models with 30 DCC, being similar to type 1 bone. Surgical instruments are generally produced from stainless steel due to its strength, hardness, corrosion resistance and ease of sterilization. Surgical materials composed of AISI 410 martensitic stainless steel generally require greater wear resistance while maintaining a sharp cutting edge, such as scalpel blades, needles, scissors and surgical cutters. 13 The XM-16 stainless steel alloy, in turn, was developed to meet the needs of a high mechanical strength/hardness, with better resistance to corrosion/oxidation and greater flexibility than conventional martensitic stainless steel. 14,15 Thus, these characteristics may explain the increase in the temperature of the drills made of XM-16 alloy after sudden use in comparison with the 420C alloy. Taking into account the negative influence of overheating caused by the drills during bone preparation and the future of implant osseointegration, the excessive and repetitive use of drills in osteotomies can influence heat generated in the bone. 16,17 Several studies 5,[18][19][20][21] have used different ways to measure temperature. In the present study, we chose to follow the model recommended by Singh et al 22 . Another factor that was considered when evaluating the temperature for implant bone bed preparation was related to the values of pressure exerted during drilling. In the present study, we used a standardized pressure of 2 kg to assess the temperature generated during bone drilling, considering that it is the most commonly used pressure in surgeries, which was also used by Sumer et al 8 and Möhlhenrich et al 23 . Pressure was standardized by using a 50 millesimal scale. The design, material and mechanical properties of the drills significantly affected their cutting efficiency and durability. ??4 The drills in our study had different designs. The Neodent drills are helical and the Dentoflex drills have three helical cutting edges of different compositions. Thus, we expected to be able to determine which drill composition would be the best for drilling procedures. We observed that time and temperature of the groups evaluated showed a significant statistical increase ($p < 0.05$) when used repeatedly. Scarano et al., ??5 comparatively evaluated the effect generated in temperature with the reuse of drills and concluded that drill wear plays an important role in heat generation that can significantly interfere in periimplant healing. Likewise, Misir et al., ??6 observed that temperature increase was observed after the thirty-fifth use regardless of the type of irrigation. Thus, the repetitive use of drills can significantly increase temperature of the cortical bone and directly influence the expected outcome. The initial drills of the two systems evaluated in all subgroups increased temperature and drilling time when compared to other implant drills. These findings suggest that these drills are responsible for disrupting the integrity of the cortical bone, which is a denser bone and consequently more difficult to penetrate. In conclusion, within the limitations of the study, we observed that the cutting time of Neodent® drills was shorter and internal temperature was higher in the S5 to S30 subgroups due to its conical geometry. Time and temperature were higher for the Dentoflex® drills in the S40 and S50 subgroups, which is explained by increased wear after reuse. Further studies should be carried out to elucidate the mechanical behavior of different implant systems after osteotomies to promote standardization among manufacturers and reduce trauma to peri-implant tissues.

11 Declarations & Statements

12 Conflict of interest

We have no conflicts of interest.

13 Year

14 Global

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Figure 1: Fig. 2 :

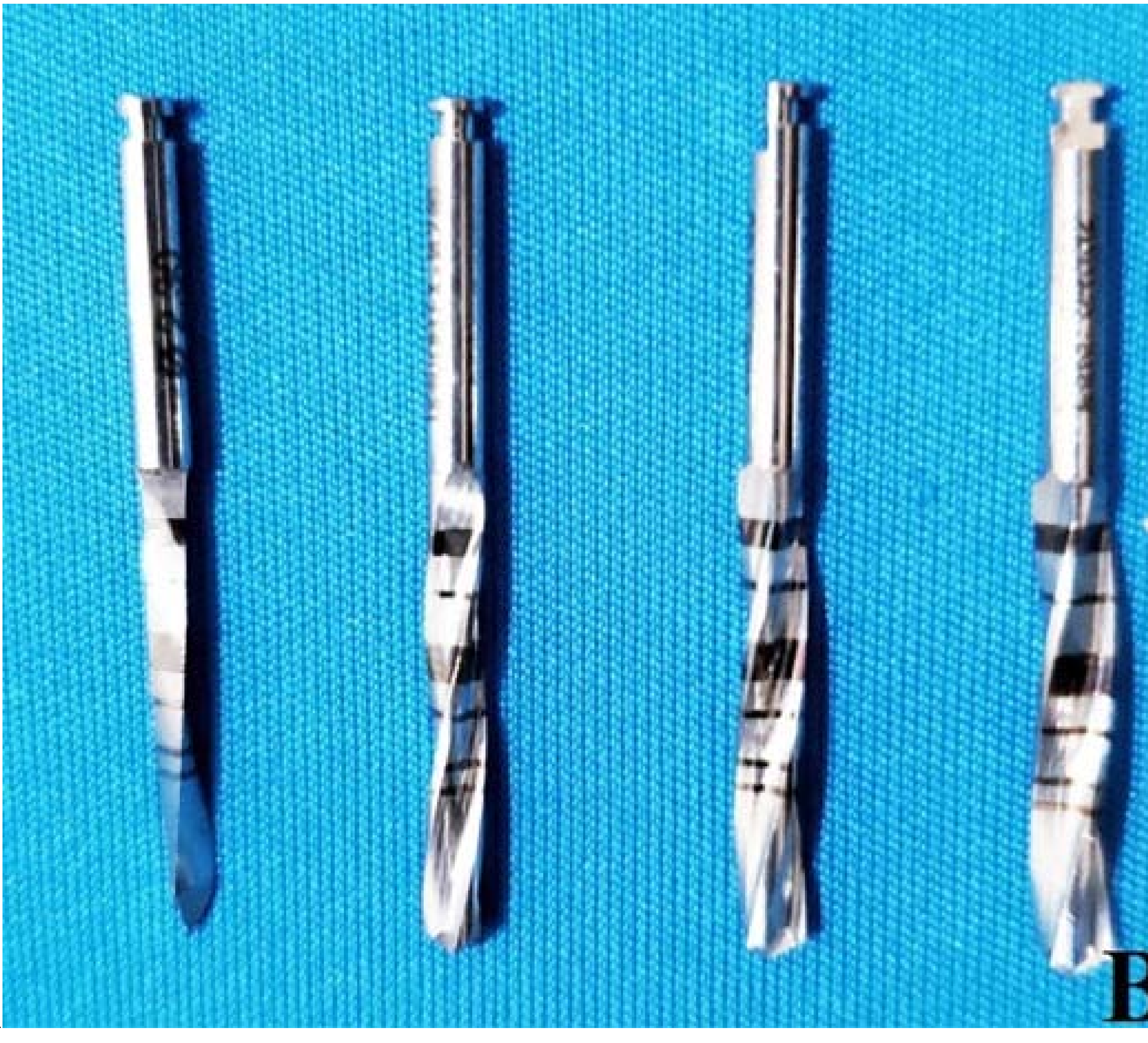
1 

Figure 2: Fig. 1 :

3 

Figure 3: Fig. 3 :

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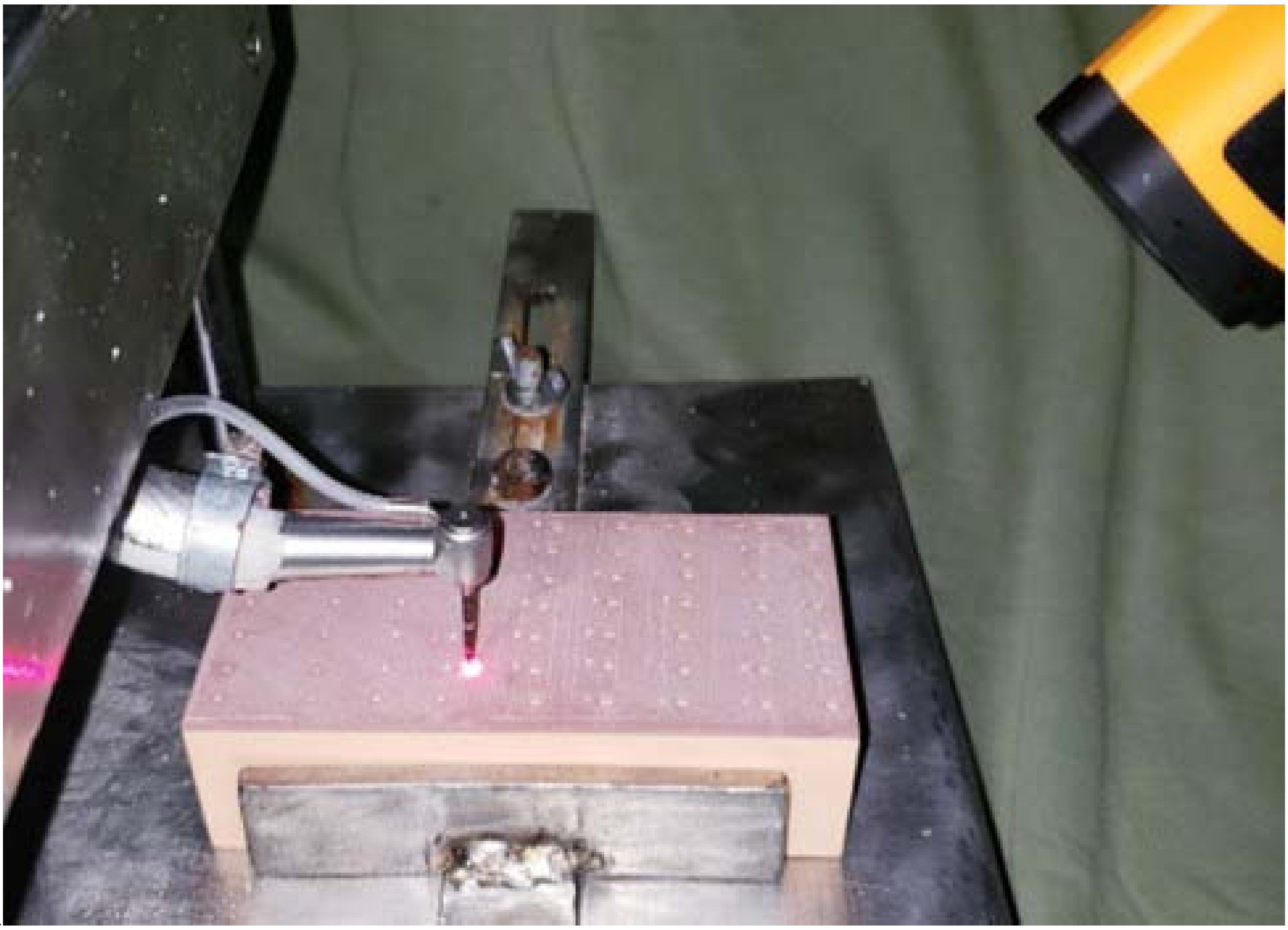

Figure 4: Table 1 :

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.2 Competing interests

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.3 Availbility of data and materials: Not applicabe

.4 Ethics approval and consent to participate:

Not applicabe (in vitro study)

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