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Semiautomatic device for in vitro/ experimental bone perforation in dental implant research☆

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ABSTRACT

Purpose: The present study presents a semiautomatic device developed to perform *in vitro* experiments using surgical drills for assisting dental implant research. It was built to perform tests independent of human direct contact, and contains an adjustable toolholder for engaging different types of implant contra angle hand pieces, in which different drills can be adapted. The researcher is able to make a range of adjustments on the machine, such as controlling the drilling force and depth.
Materials and methods: The device was tested on samples of both synthetic and natural bone with type I density, and a sequence of drills selected to perform the perforations. Drilling time and perforation force exerted during drilling were evaluated, as both parameters are required to be standardized.
Results: It was observed that the drilling performed using the device was uniform using both types of bone, although the drilling time for the synthetic bone was higher. All perforations were exactly on the spot previously determined, and without variations in drill angulations. The perforation force was higher for the lance pilot drill for both bone types, and the natural bone required a higher axial force than the synthetic bone.
Conclusion: Thus, we consider this device trustable to perform standardized analysis and provide accurate results. It can be used for tests performed in universities and companies that develop dental implant materials and products.

1. Introduction

Laboratory dental research usually requires developing techniques and devices that direct their study closest to simulate the oral condition. Studies in implantology use bones of different natural sources (Kim et al., 2008; Tsai et al., 2009; Otha et al., 2010) and also synthetic bone blocks which enable a great number of samples to be standardized and tested (Kim et al., 2008; Tsai et al., 2009; Oliveira et al., 2016). In addition to the different bone types available, devices or machines were also developed aiming to perform trials with implants and to support the evaluation of different variables of each *in vitro* study (Eriksson and Albrektsson, 1983; Eriksson and Adell, 1986). Some of these experimental studies evaluate drilling parameters, such as drilling time, drilling temperature and the wear of each drill. These tests are of extreme importance for targeting clinical research as well for the use of different materials and techniques by clinicians during implant placement surgeries (Oliveira et al., 2016). In this way, it is important that the devices present conditions for standardized tests to generate more precise results and conclusions.

☆ **Type of Paper contribution**: Reports of new instruments or technical innovations.

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Based on that necessity, we developed a semiautomatic device that uses surgical drills for perforations in different bone densities, whether natural or synthetic. The operator/researcher does not have direct contact with the operational part of the device, which reduces the intervention during the experiments, and increases the dynamics, optimization and standardization of the tests. It presents reduced dimensions favoring transportation, work and affordable cost for research in universities and in dental products development, allowing the reproducibility and standardization of scientific works with new products and materials.

2. Material and methods

2.1. The device

The device for bone perforation is composed by a platform that supports its pieces (Fig. 1a), two hydraulic cylinders (Fig. 1b), and two reservoirs (Fig. 1c) which are used as a support base for the loading cell. Each cylinder has a rod that functions as a toolholder (Fig. 1d) for engaging the implant contra angle handpiece (Fig. 1f), where each drill is adapted. This toolholder is adjustable for any brand of implant handpiece. In this study we used the Koncept 20:1 handpiece (Kavo Kerr, Illinois, USA). This allows the up and down movements of the drills, providing parallelism. The feed rate of the device is controlled by a flow-regulating valve (Fig. 1e) which will determine the drilling time. The toolholder also has a course limiter consisting of a micrometer and an electro-mechanical deactivator (Fig. 1g) that limits the working depth of the drill, and is an important factor in standardizing the drilling process. On the hydraulic fluid reservoir there is the platform (Fig. 1h) that supports the bone samples, which are fixed by a vise. Under it there is a sensor that transmits the force exerted during the drilling of each drill on the bone samples (Fig. 1i).

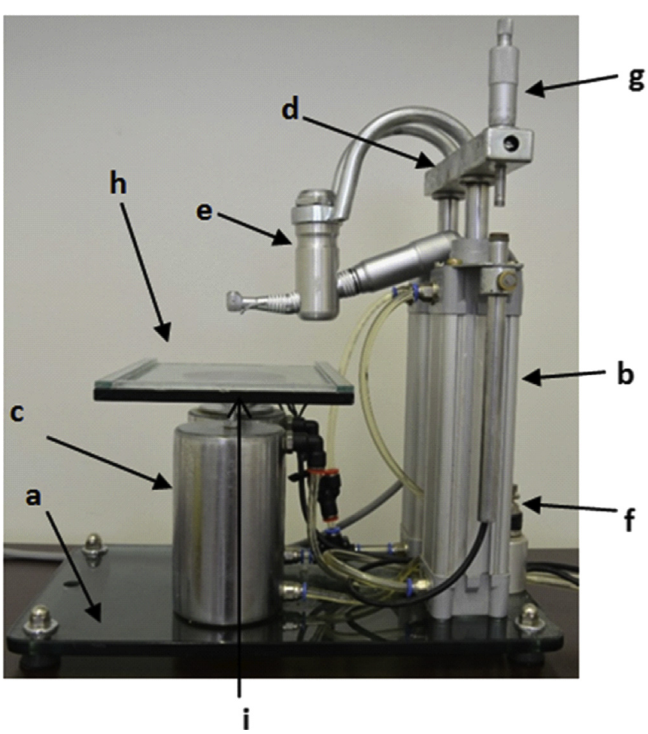

Fig. 1. Device for bone perforation composed by: platform that supports its pieces (1a), two hydraulic cylinders (1b), and two reservoirs (1c) which are used as a support base for the loading cell. Toolholder (1d) for engaging the implant contra angle handpiece (1e), flow-regulating valve (1f), micrometer and an electro-mechanical deactivator (1g) that limits the working depth of the drill. Platform (1h) that supports the bone samples and a sensor that transmits the force exerted during the drilling of each drill on the bone samples (1i).

2.2. Testing the device

We used two types of samples for testing the standardization of drilling performance by the device, which were a polyurethane synthetic bloc (Nacional Ossos, Jáu, Brazil) and a natural bone bloc of bovine ribs. Fig. 2a exemplifies a synthetic bone block simulating type I density (40 PCF or 0,64 g/cm^3), and on dimensions of 5 cm (L) × 2,5 cm (W) × 2,5 cm (H), and Fig. 2b exemplifies bovine ribs with the same dimensions as the synthetic bloc. These dimensions were accurate for fixing the blocs on the vises. Fig. 3 shows the samples of the synthetic and the natural bone blocs.

For the drilling we used the Full Osseointegration kit that provides drills for type I bone (Conexão Sistemas de Próteses, São Paulo, Brazil). Table 1 shows the sequence of drills used in this study following manufacturer's recommendations.

2.3. Time of drilling

The perforations were performed on both synthetic and bovine bone blocks simulating the insertion of a 3.75 × 10 size implant. The micrometer was calibrated to perform the drilling with 10 mm depth with a rotation speed of 800 rpm. The drilling time (feed rates) was controlled by a timer for every drill since the toolholder began to move until the end of drilling at 10 mm.

2.4. Measuring the drilling force

The drilling force was measured when the drill contacted the bone samples and exerted a force. This force was registered by a display placed on the controlling box. A camera coupled to the controlling box also registered this force and later (in slow motion mode) the maximum value of the force exerted on the bone sample was recorded.

2.5. Measuring of the temperature

A Kiray 50 digital thermometer (Kimo® Instruments, France) was used to record and measure the temperature before and after the milling procedures in different block samples (Fig. 4a). The readings were recorded twice, at the beginning and at the end of the use of every drill, directing the infrared ray inside each spot (Fig. 4b). The thermometer was positioned 30 cm far from the spot, and has a reading range from −50 °C to 380 °C, and with a response time less than 1 s (Fig. 4c). We exposed the results as the variation of the temperature before and after the drilling procedure.

3. Results

It was observed that all movements of up and down exerted by the implant handpiece/drills were precisely standardized. Every following drill drilled on the same spot as the previous, and all of them in 10 mm as determined by the micrometer. The time of drilling was approximately one second longer on synthetic for all types of drills (Table 2).

The perforation forces decreased as the different drills were used on both synthetic and natural bones (Table 3). The perforation force required was higher when using the lance pilot drill for both bone types, the first drill used, and the lower drilling force was with the 3.2 drill, the last one. The natural bone required a higher perforation force than the synthetic bone (Table 3).

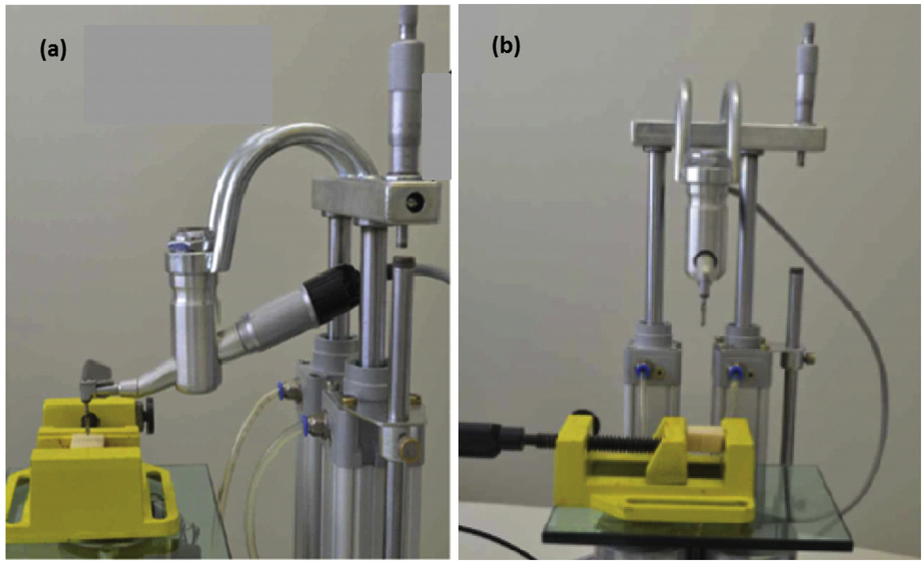

Fig. 2. (a) Lateral view of the toolholder and the contra angle handpiece with a drill in place for drilling the bone block sample, and (b) front view of the device and the vice holding a bone block precisely.

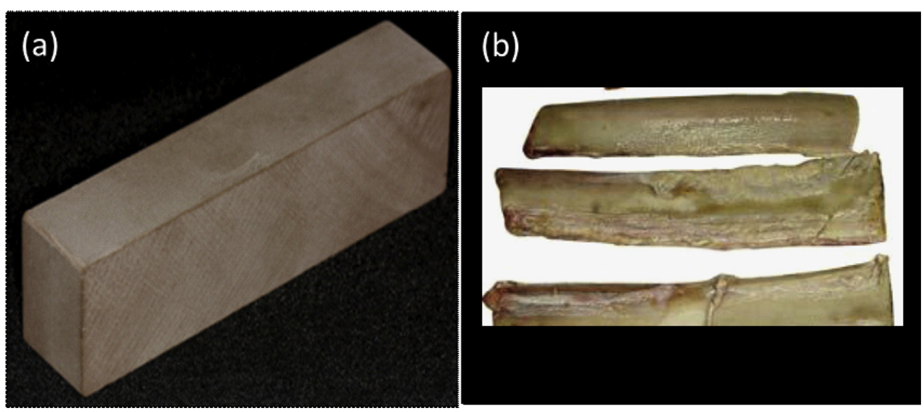

Fig. 3. Synthetic (a) and Natural bone block samples (b). Both have density of type I bone and the natural bone is derived from a cow rib.

Table 1
Sequence of drills recommended by the manufacturer for bone type I density.

Length of Perforation (mm)	Sequence of Drills				
10	Lance Pillot	2	2.4/2.8	3	3.2

At the beginning of the experiment, the temperature of the synthetic blocks was 21.76 °C, while the temperature of the bovine bone blocks was 20.1 °C. The variation of the temperature before and after the drilling decreased after the use of the lance pilot drill for both bone blocks (Table 4). The variation of the temperature was similar at both bone blocks (Table 4).

4. Discussion

Although laboratory and animal studies have lower scientific evidence strengths compared to clinical trials, they are important steps to knowledge and to better target clinical research. It is important that *in vitro* studies are designed in a similar way to the clinical situations they want to perform, making it important to develop devices and tools that enable more accurate tests (Cordioli et al., 1997; Augustin et al., 2008). The present study details the development of a device for research in dental implantology and the tests performed by it show that it is able to perform the perforations accurately and without the

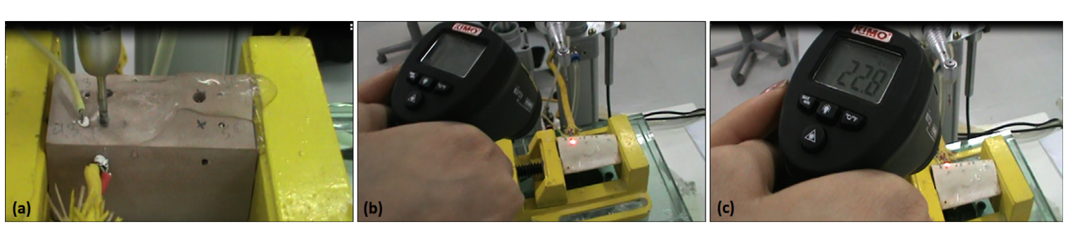

Fig. 4. (a) Beginning of the drilling procedure; (b) A thermometer was used to record and measure the temperature before and after the milling procedures in different block samples. (C) The readings were recorded twice, at the beginning and at the end of the use of every drill, directing the infrared ray inside each spot.

Table 2
Time of perforations in seconds (s) for each type of drill at 10 mm depth for both synthetic and natural bone blocks.

Depth of Drilling	Sequence of Drills	Time of perforation (s)	
		Synthetic bone	Natural bone
10 mm	Lance Pillot	9.7	8.92
	2	9.79	8.38
	2.4/2.8	9.72	8.85
	3	9.37	8.9
	3.2	9.2	8.78

Table 3
Perforation force in grams (g) for each type of drill at 10 mm depth for both synthetic and natural bone blocks.

Depth of Drilling	Sequence of Drills	Perforation force (g)	
		Synthetic bone	Natural bone
10 mm	Lance Pillot	2239	4884
	2	1513	1892
	2.4/2.8	583	1725
	3	482	1479
	3.2	291	1458

Table 4
Temperature variation (°C) for each type of drill at 10 mm depth for both synthetic and natural bone blocks.

Depth of Drilling	Sequence of Drills	Temperature (°C)	
		Synthetic bone	Natural bone
10 mm	Lance Pillot	1.95	1.20
	2	1.35	0.01
	2.4/2.8	1.35	0.60
	3	1.05	0.70
	3.2	0.95	0.70

interference of an operator, allowing more real interpretation of the obtained results.

Several devices were developed and their performances and results were published in the literature. They used different samples for testing and different machine programming. Some of these devices for bone drilling, for example the ALG-100 (Prvomajska, Zagreb), present options for regulating the drilling speed in the machine itself, but they present a limitation of use of drills (Augustin et al., 2008). In this study we present a device that is able to adapt any surgical drill of any brand, and the drilling speed can also be controlled.

However, with this device it is possible to control the speed of drilling temperature. That device performed the tests as expected by its developers, but the limitation we see is it is not a mobile device. Devices designed to perform standardized tests with drilling are usually not mobile devices. This particularly limits its use, because only the research group that developed it can perform tests or other researchers have to go to their location and use it. The device we present has the advantage of being easy to transport and can be settled on any laboratory bench, unlike some test machines that are fixed in a particular research center. Thus, different research groups would have access to this machine and could reproduce the tests performed by us, using different conditions, different brands of hand pieces and drills or samples.

Another positive point of our device is that it is not controlled or operated directly by the researcher during drilling trials, but controlled by the command box. Also, the drills move in a single direction without slopes. Other devices already published in the literature are controlled and operated by the researchers, who can control the handpiece and perform the perforations differently during every test, as well as the direction of movement of the drills. This type of device does not allow concentricity of the drillings, which may interfere with the milling temperature and the cutting force (Boa et al., 2015; Schwarz et al., 2015). In addition, our device contains a stop that controls the drilling depth, providing an accurate measurement, and the tool-holder rod fixed to the cylinders enables concentricity of the perforations.

We tried to adjust this device to be as precise as possible for the drilling parameters, and we tried to adjust it to control the forces performed on different densities of bone samples, thus it could be used in various experimental designs. We used the value of 2 kg as being the force applied in real implant placement surgeries. Other studies have also used this value (Lavelle and Wedgwood, 1980; Cordioli and Majzoub, 1997; Ercoli et al., 2004). During the tests we observed that axial drilling forces had different readings according to the type of drill and the type of bone density. We also noticed that the drilling force is not the same throughout the course of the drilling, and that in a cortical bone the force of 2 kg is required to drill the cortical bone, but when it reaches the cancellous bone, this force will be necessarily reduced. In this way, we programed the control box to regulate the force in a range of 0–7 kg, according to the needs of each study.

We suggest that the control of the chronometer by the researcher may be a limitation of our device. We observed that during the execution of the experimental tests, the advancement and approximation of the drilling varied in 1 s for bone type I and type IV. The devices developed in the future could have a timer that accurately records the time without relying on an operator.

5. Conclusion

Therefore, we considered the device presented efficient for the research in implantology performing tests of bone drilling using different drills or burs and specimens. This device allowed standardizing the sense and intensity of forces with absence of external interference, which provided greater precision. It can be used for tests performed in universities and companies that develop dental implant materials and products. In addition, the analysis of the drilling force, the milling time and temperature variation during the drilling procedure can be used to evaluate different milling protocols with different drill designs, and the surgical site perforation performed for the placement of implants with different sizes and macrostructures in synthetic and natural bone samples that mimic different bone densities.

Conflict of interest

The authors declare to have no other conflicts of interesting regarding this research.

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