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Biomechanical test materials for Bone drilling; the effects of temperature increase during drilling

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Bone biomodels are often used for tests of drilling without flush due to the simplification of the test procedure. The temperature of the model made of polyurethane or epoxy resin increases during drilling test. The measurement of temperature will reveal the effects on the mechanical tests. This study describes the experimental drilling tests under constant thrust force using Sawbones® test materials. Characterization of drilling includes measurements of drilling properties such as torque and temperature rise during drilling. The difference of drilling behavior among Sawbones® test materials is discussed with taking into account the effect of rotation speed, feed rate, and applied thrust force.

Keywords: Bone drilling, sawbones model, thrust force, torque, cutting temperature

1. Introduction

Drilling is in the surgical procedure in medical specialties of dentistry or orthopedics. Bone biomodels are used in surgical training or evaluation of medical devices. The current market has bone biomodels made of polyurethane or epoxy resin, but these biomodels are reported to have the gap in drilling properties such as thrust force or torque compared to natural bone [1]. Therefore, researchers have developed new materials for biomodels providing the biomodels that fulfills the required demands [2, 3].
In many cases of evaluation or test of medical devices, the tests have been performed without flush as a simplified procedure, although it is known that there is a gap from the real operation. Therefore, the authors previously reported the impacts of temperature rise during drilling on acrylic resin for drilling bone biomodel without flush [3]. In this study, the conventional models made of polyurethane and epoxy resin are reported in order to show the dependence on materials for further designing bone biomodels.

2. Methods

2.1. Materials

Three materials were prepared from Sawbones® test materials: a cortical bone model (Composite sheets #3401-06, Sawbones) (called as EP below) made of epoxy resin and glass fiber, and cancellous bone models (Solid Rigid Polyurethane Foam Block 20 pcf #1522-03, and 50 pcf #1522-27) (called as PU20 and PU50 below) made of polyurethane foam.

2.2. Methods

Drilling test rig included a spindle (Electrobroche SD 5084, Precise, France), a strain gauge, and a displacement sensor. The rotation of a drill bit was numerically controlled. Work pieces were pasted on a work table. The axial thrust force was applied to the drill bit under the applied constant load. Drilling was performed for 5 mm. Thermal images were taken with the infrared camera (FLIR SC7000), perpendicularly set to work pieces. Cutting chips were gathered after drilling tests for morphological characterization.

2.3. Results

Figure 1 represents the typical evolution of torque, temperature rise (ΔT), and displacement as a function of time during drilling in PU50 under 20 N and 1,000 rpm. Drilling in PU50 takes about 2 seconds for 5-mm depth. Torque increases along the penetration of the drill bit and reaches its maximum value slightly before the maximum depth at 5 mm, and keeps its value until the end of drilling. ΔT increases drastically at the beginning of drilling firstly until about 50°C and then increases again until about 120°C around the endo of drilling.

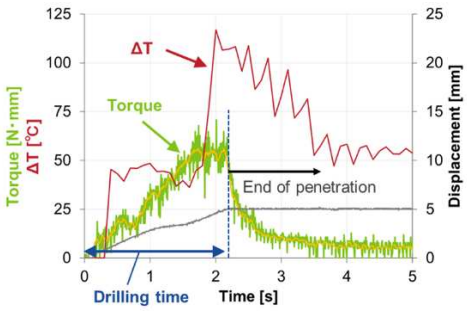

Figure 1: Typical curves of drilling properties in PU50

3. Discussion

It can be plastic deformation of material due to creation of cutting chips, and friction between cutting edges and emerging surface of work material. Along the progress in penetration of drill bit, there would be additional heat sources due to the cutting chips evacuating the borehole, having both deformation and friction through the flute of drill bit. This effect is thought to be seen in the second peak of ΔT in Figure 1.

4. References

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