PROPOSAL OF NOVEL ABRASIVE MACHINING METHOD FOR PREPARING THE SURFACE OF PERIARTICULAR TISSUE DURING ORTHOPAEDIC SURGERY OF HIP JOINTS SURFACE

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Introduction

One of the primary methods used during orthopaedic procedures is the surface machining of the cartilage and bone tissue based on drilling, cutting and milling [1]. This type of operation involves thermal energy emission [2], tissue destruction and direct impact on the body [3]. Therefore, the force of the cutting process, temperature, shape and quantity of chips, and the characteristic of the cutting process should be examined. However, the popularity of standardized surgical procedures causes no changes in the processing technology and the availability of specialized surgical equipment. The above study focused on developing a proprietary method of machining the periarticular hip surfaces, focusing on abrasive treatment to remove diseased or damaged tissue. The obtained results provide the first time in literature essential information regarding cartilage and bone tissue abrasion performance.

Materials and Methods

The silicon carbide (95-98% SiC) and brown fused alumina (94,5-97%BFA) grains were used to manufacturing abrasive tools. The polyamide (PA6) rollers with a diameter of 12 mm were covered with mixed styrene-modified epoxy resin with a hardener and grains. Grains with granulation from 90 to 390 um were used. The oscillating movement of the tool in the range of 0.25 to 1 mm in two directions along the shape of the ellipse has been applied. Fragments of pork femoral heads were subjected to machining tests with specific motion kinematics in dry and wet cutting conditions, using a precise UMT Bruker Tribometer equipped with a 2-dimensional force sensor DFM-20 with a measurement range 2 to 200 N and resolution of 10 mN. The cutting temperature was measured with a thermocouple localized in the polyamide roller surface. Primary parameters measured during experiments were normal force F_N, tangential force F_T and penetration depth Δz [mm]. The tool position in the z, y and x orientation, penetration depth v_z, movement v_x and v_y velocity and Δy, Δx movement ranges were also evaluated. A force sensor in the Z-axis direction monitored a constant load in fourth levels: 5, 10, 15 and 20 N. The friction coefficient was determined experimentally using the tribometer software. The chip forming mechanism was analyzed using a TESCAN Vega 3 scanning electron microscope (SEM) with a secondary electron detector.

Results and Discussion

TABLE 1 presents the friction forces during machining with an abrasive tool. The presence of water allows for lower values of F_{Tmin} and F_{Tavg} for both types of abrasion tools. As a result, the value of the total force increases with the reduction of the grain size. However, the performance of the BFA tool is stable, and the standard deviation is only 0.2 N to the SiC deviation of 0.8 N.

TABLE 1 Maximal, minimal and average tangential force results for different abrasive tool materials and conditions.

Force [N]	BFA wet	SiC wet	BFA dry	SiC dry
F_{Tmax}	14,45	11,20	10,12	11,58
F_{Tmin}	1,65	1,32	2,19	2,68
F_{Tavg}	5,51	5,68	4,80	6,46

The mean value of friction coeffcient μ for cartilage tissue under wet external-jet conditions is $\mu_{c\_ext} = 0{,}45\pm0{,}02$ and for cartilage tissue under wet internal-jet (water injected trought polyamide roller) $\mu_{c\_int} = 0{,}07\pm0{,}02$. The comparison between bone tissue $\mu_{b\_int} = 0{,}11\pm0{,}02$ and cartilage tissue μ_{c_int} shows that erosive machining process is similar.

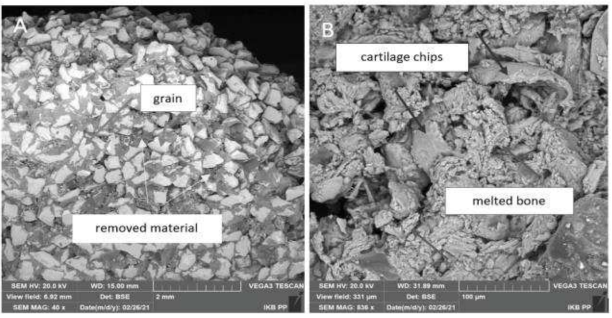

FIG. 1. The effects of machining of cartilage and bone in wet conditions: a) tool surface, b) chips after wet machining.

FIG. 1 is a view of an abrasive surface with remains of bone and cartilage among the grains. In the dry processing of cartilage and bone tissue, the residual cartilage material limited the abrasion mechanism. As a result, the chips did not take any characteristic shapes, creating a slime sticking to the grains. This phenomenon reduced machining efficiency. The separation of tissue fragments from the surface in the form of chips with a continuous, smooth shape was observed during the wet abrasive. During the machining of bone tissue, single fragments of chips were observed. The chip forming stage can be divided into three steps: the single-pass formation of the chip, melting due to multiple tool movements and the final chips exit from the workspace. Regardless of the grain size, this process results in a chip size from 50 to 5 μm. Temperature measurements showed no increase beyond the measuring accuracy range of ±0.4°C.

Conclusions

This machining process method may become a starting point for more extensive research machining and accompanying procedures. In addition, the results highlight the potential of the proposed tool concept in designing new methods for treating periarticular tissues.

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