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Mechanical and tribological properties of tricalcium phosphate reinforced with fluorapatite as coating for orthopedic implant

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ABSTRACT

In this work, the tribological and mechanical behaviour of tricalcium phosphate-Fluorapatite (β-TCP-Fap) bioceramic was investigated. Indeed, the Fluorapatite was added to the tricalcium phosphate to improve its mechanical properties. The mixture of both powders is considered as a bioactive coating that is likely to be used in orthopaedic implants. The assays were conducted on the cylindrical blocs by compacting the mixture in a metal mould. The characteristics of the specimens were investigated with various methods, including optical microscopy, scanning electron microscopy (SEM), nanoindentation and a ball-disk tribometer. The lowest volume wear was measured for β-TCP-26.52%Fap biocomposites under dry condition. Hence, β-TCP-26.52%Fap specimens have revealed the best wear resistance properties. The results would be helpful to fully understand the effect of the addition of the Fluorapatite to β-TCP matrix on its tribological properties.

1. Introduction

The problem of friction. and wear in the prosthesis for the substitution of hip joints and knees have been addressed by many authors [1–3]. Attention has been drawn to the development of various coatings to supplement the function of the current implants. In the same vein, many researchers have advocated that calcium phosphate ceramics are biocompatible and may develop interactions with human living bone tissues. In the literature, it is well known that the application of monolithic tricalcium phosphate (β-TCP) at high load bearing conditions is limited due to its brittleness, poor fatigue-resistance and poor mechanical resistance [2]. To overcome this problem, researchers have attempted to synthesize β-TCP-based composites with better combination of physical properties than monolithic β-TCP. Thus, Fap has recently been the interest of researchers due to its chemical composition similar to the bone mineral, and therefore its excellent biocompatibility [4]. In fact, the human bone contains about 1 wt% of Fluor that is known as an effective element in caries' inhibition [4]. It is in this context that the present work lies as an attempt to investigate the tribological behavior of β-TCP-Fap composite coatings. Considering the interesting bioactivity of fluorapatite, however, it is surprising that very limited research works have been conducted on the synthesis and characterization of β-TCP-Fap composite coatings so far.

The aim of the current study is to explore the effect of adding fluorapatite (13.26; 19.9; 26.52; 33.16; 40 wt% corresponding to 0.5; 0.75; 1; 1.25 and 1.5 wt%, respectively, of Fluor) to pure β-TCP on fretting corrosion against alumina counterbody. In this work, the fracture toughness, hardness, friction coefficient and the volume wear are presented and discussed.

2. Material and methods

The fluorapatite powder was synthesized using a wet-chemical method [4]. A calcium nitrate solution was gradually added to a boiling solution containing di-ammonium hydrogeno-phosphate, and ammonium fluorine solution was added to the mixture in order to adjust the pH to 9. The obtained precipitate was filtered and calcined at 500 °C. The pure commercial tricalcium phosphate powder (Medicoat, 99.3%) was used as base material. The approximate Fap-β-TCP representatives were [{13.26 wt%, 86.74 wt%}

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Table 1
Experimental conditions for wear tests.

Applied load, F, (N)	3, 5 and 8
Sliding time (min)	30
Sliding distance (m)	≈113 m
Sliding velocity, v	100 rpm ≈ 0.063 m/s
Diameter of alumina ball (mm)	16
Diameter of wear track (mm)	12
Relative humidity (%)	30–40

{19.9 wt%, 80.1 wt%}, { 26.52 wt%, 73.48 wt%}, {33.16 wt%, 66.84 wt%} and {40 wt%, 60 wt%}, respectively. The powder mixtures were milled in ethanol and then desiccated at 70 °C for 24 h.

Fap-β-TCP composite were cut in cylindrical compacts of the size of 30 * 5 mm for friction test. The heat treatment of the green compacts was carried out at 1300 °C for 1 h.30. It is worthy to mention that three values of the applied loads were considered, namely 3, 5 and 8 N. These loads were chosen to ensure severe tribological conditions in these investigations [1,5,3].

Friction and wear tests were conducted using a pin-on-disk tribometer that was developed in the National School of Engineering of Sfax. An Alumina ball with a diameter of 16 mm and surface finish of 0.06 μm (Ra) was used as counterface. The specimens were fixed on the rotating disk surface. All experiments were conducted under dry conditions at room temperature and using a constant rotation speed. Some retained test conditions are reported in Table 1.

After testing, the samples and the ball were taken out and cleaned with ethanol. The worn surfaces of the specimens were scanned under surface profilometer to obtain the wear volume.

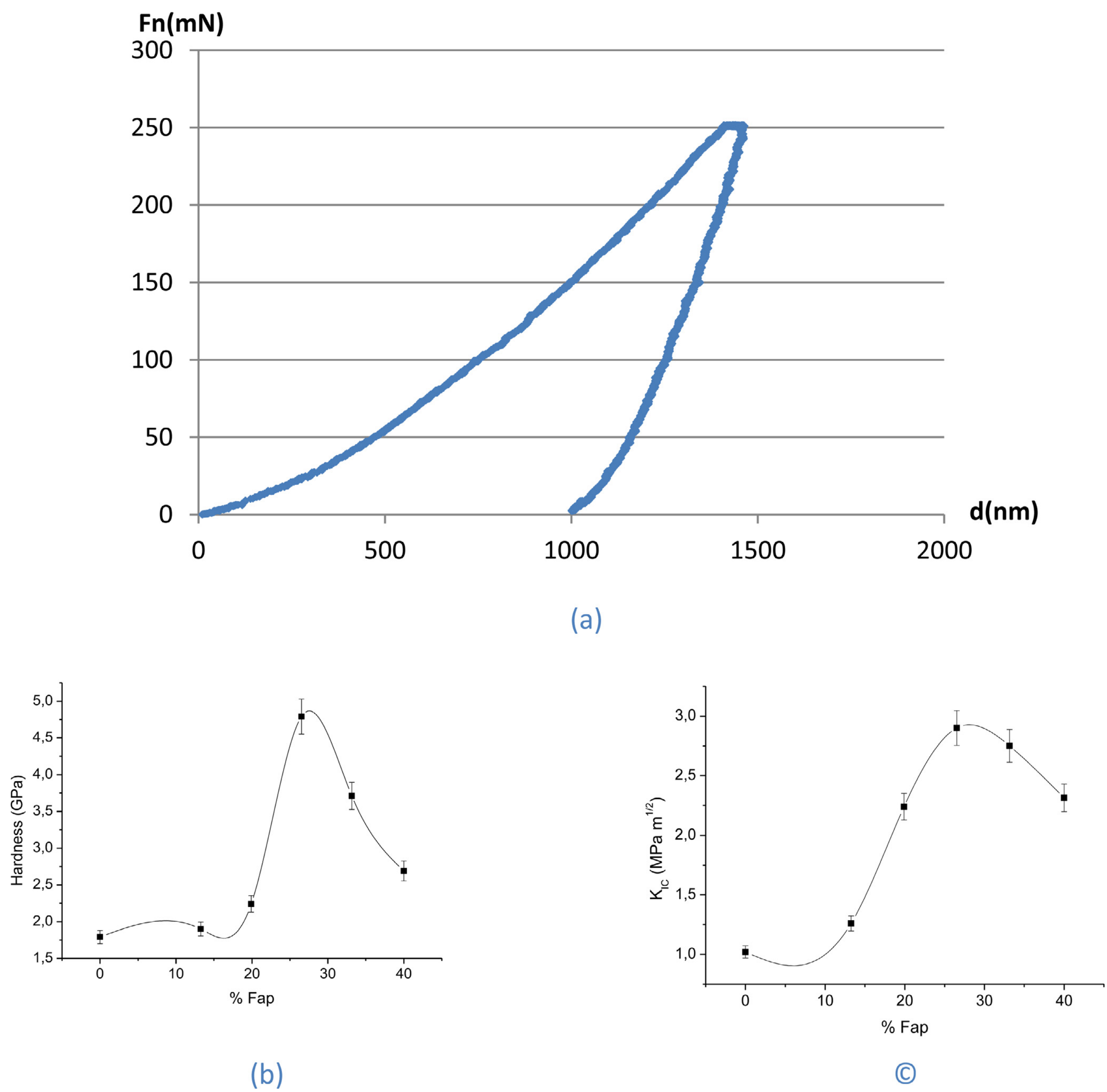

Fig. 1. (a): Example of a Load–displacement curves obtained by nanoindentation, (b): Hardness of the β–TCP-Fap versus %wt Fap; (c): Fracture toughness versus %wt Fap.