Resorbable Tricalcium Phoshpates for Bone Tissue Engineering: Influence of SrO Doping

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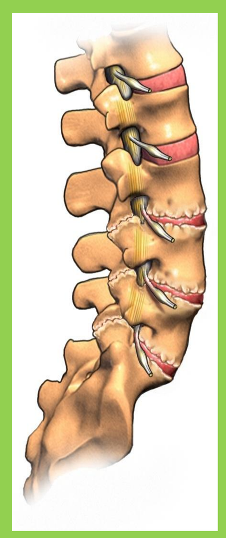
Abstract: SrO doped TCP was synthesized via a wet precipitation process. The synthesized TCP was processed into pallets and then characterized an tested to determine mechanical and biological properties. Through X-ray Diffraction analysis (XRD) it was found that the synthesized TCP was pure beta phase. Archimedes principle was used to determine the density of the samples. The density increased from 95.1% (+/- 2.5) to 99.4% (+/- .64) of the theoretical density of TCP with 5% Sr addition. The compressive strength followed a similar trend and increased from 121 MPa (+/- 21) to 185 MPa (+/- 37) with 5% Sr addition. It was concluded that SrO doping served to improve the mechanical properties of the TCP matrix.

Objective: To determine the mechanical and biological effect of SrO dopants on a Tricalcium Phosphate matrix

Introduction



- Resorbable calcium phosphate based ceramics have been studied for bone implant materials because of their biocompatibility and similar composition to natural bone[1].
- Tricalcium phosphate ceramics are widely used for clinical applications because of their bioresorbable and osteoconductive nature in a physiological environment. These properties allow a tricalcium phosphate based implant to be absorbed into the body and be completely replaced with newly grown tissue.

- However, the uncontrolled rate of bioresorption and low mechanical strength of TCP limits its use as a functional implant [2]. It has been shown in previous studies that embedding metal dopants into a TCP matrix can improve the bioresorption and mechanical strength[3].
- The purpose of this study is to determine the mechanical and biological effects of SrO on TCP.

Synthesis and Processing of SrO TCP

Synthesis

- 0.066 moles Ammonium Hydrogen Phosphate dissolved in 100 mL DI Water → pH of solution adjusted to 9.5 with addition of Ammonium Hydroxide
- 0.1 moles of Calcium Nitrate dissolved in 100mL of DI water → Corresponding amount of Strontium Nitrate added to solution
- Calcium-Strontium Solution added to Hydrogen Phosphate solution dropwise while pH was maintained at 9.5 using Ammonium Hydroxide
- → Precipitate was vacuum filtered then dried for 12 hours at 75 C
- → Resulting powder was crushed and calcined at 800 C for 2 hours to obtain β-TCP

Processing

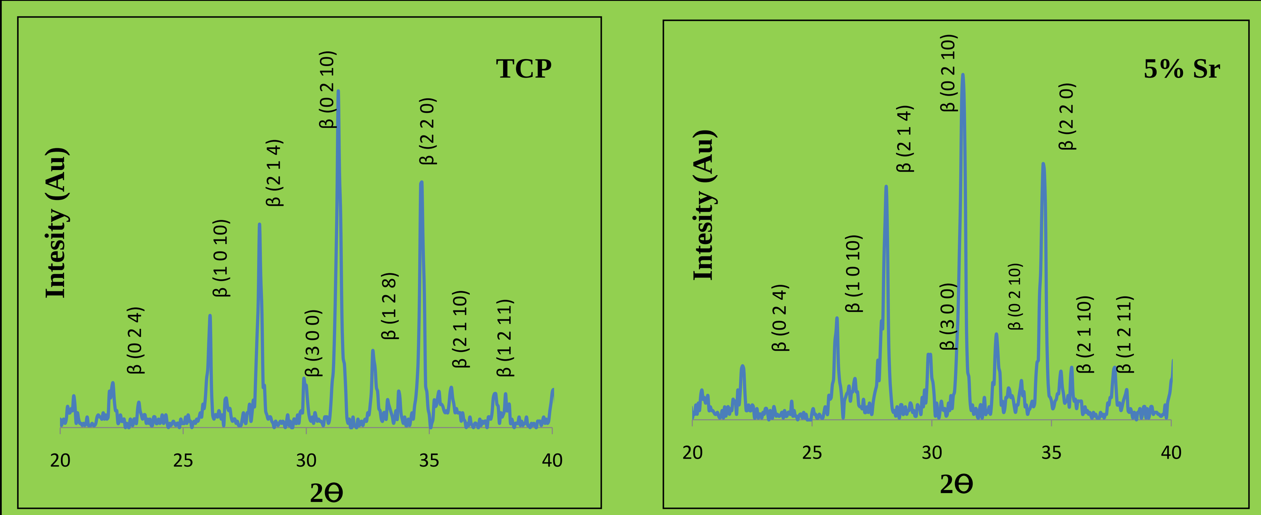
- Calcination 650 C 2 Hours
- → Uniaxial Press
- → Cold Isostatic Press 60 ksi 5 Minutes
- → Sintering for 2 Hours at 1120ºC

Synthesizing TCP makes it possible to add the SrO dopant during the formation of the calcium phosphate, allowing the dopants to become chemically bonded into the TCP matrix. Synthesizing the TCP is also more cost effective than purchasing high purity commercial TCP powder.

Results

Phase Analysis

- TCP may take the form of several different phases, with alpha and beta phase being of primary interest.
- Beta phase TCP has a higher density that alpha phase (3.07 g/cm^3 vs. 2.86 g/cm^3) and has a more controllable dissolution rate in a biological environment.
- Therefore, the samples were sintered below the beta to alpha phase transition temperature of 1125° C to ensure the formation of nearly pure beta phase TCP.

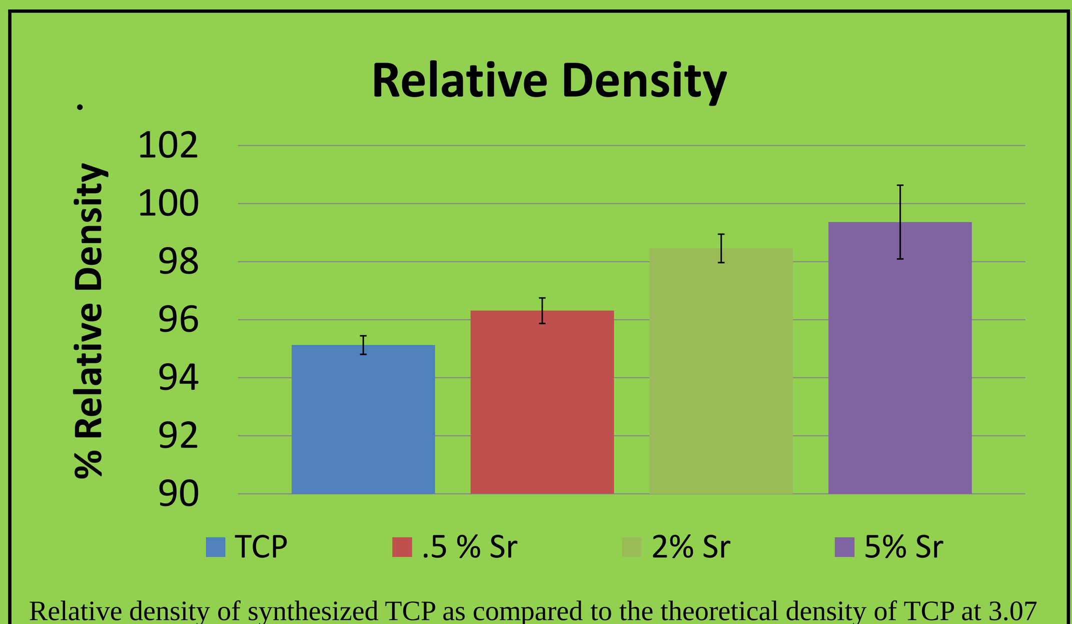


XRD (X-ray Diffraction) analysis of pure TCP and 5.0 mol % SrO doped TCP. XRD was taken after sintering of the samples at 1120° C.

The material was characterized through X-ray Diffraction (XRD). The XRD readout indicated that that the material formed was nearly phase pure β-TCP.

Density

- Achieving a high density of the TCP ceramic is essential to maximizing the strength of the implant.
- Full density is achieved by sintering the ceramic material at 1120° C. The density was measured using Archimedian's principle.

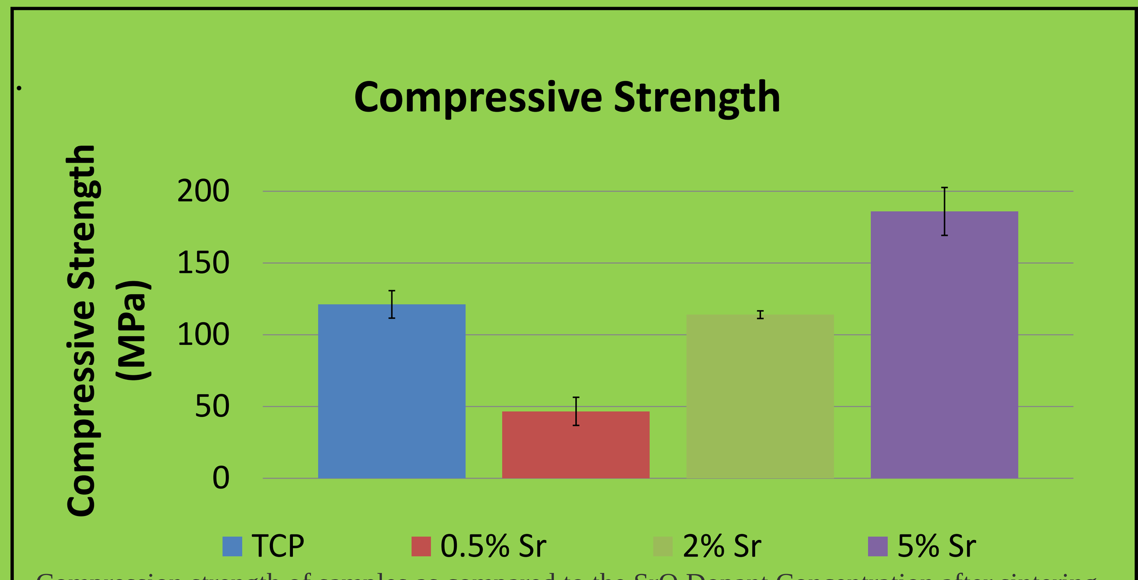


Relative density of synthesized TCP as compared to the theoretical density of TCP at 3.07 g/cm^3 . Metal addition to TCP was not calculated into the theoretical density due to the relatively small concentrations. Error bars are standard error with n = 4.

The density of TCP increased to 99.3% theoretical density with the addition of Sr dopants.

Compression Testing

- A high compressive strength is required for the implant material to insure that the implant wont fail in use.
- TCP degrades over time in a physiological environment, so the initial compressive strength of the implant is important.



Compression strength of samples as compared to the SrO Dopant Concentration after sintering at 1120°C. Error bars are standard error with n = 5.

The compressive strength of the doped TCP followed the same trend as the density, increasing with the added Sr concentration.

Summary

- Phase analysis via XRD indicated that the samples prepared were pure beta phase TCP
- Increasing SrO dopant concentration increased the density from from 95.1% (+/- 2.5) to 99.4% (+/- 0.64) with SrO addition
- Compressive strength increased from 121 MPa (+/- 21) to 185 MPa (+/- 37) with SrO addition

Further Study

- In-vitro analysis of samples in a Simulated Body Fluid (SBF) environment
- Determination of mechanical strength vs. time in SBF
- Analysis of dissolution rate of SrO doped TCP in SBF
- Cell culture studies to determine cell attachment to the surface of the sample over time
- In-vivo study (using rat model) to determine ion concentration using atomic absorption spectrophotometer

References:
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3 . Zachary Seeley, Amit Bandyopadhyay, and Susmita Bose, "Tricalcium Phosphate Based Resorbable Ceramics: Influence of NaF and CaO Addition," Mat. Sci and Eng., **28** [1], pp. 11-17 (2008).

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