The Stability of Biological Apatite in the Presence of Strontium

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INTRODUCTION:

Strontium plays important role in stimulating the growth of osteoblasts and enhancing the formation of new bone. Therefore, a strontium related compound - strontium ranelate (SR) has recently been suggested for use as a daily supplement to treat osteoporosis. However, the true effect of strontium to the stability of hydroxyapatite (HAp) has not been well understood yet, such as why higher concentration of strontium was normally detected in new bone, but seldom in old bone. In particular, strontium-substituted apatite was widely reported much higher soluble than pure HAp, although some report postulated that Sr40-HAp may be more stable than pure HAp, thus HAp should be the stable phase, not a strontium-substituted apatite. The most explanation was only attributed to calcium ion easily substituted by strontium ion on bone surface, but lacking of thermodynamic principle to support it. Therefore a recent reported solid titration method has re-checked the strontium system and found solubility of strontium-substituted apatite indeed increased with increase of strontium content (Fig. 1), the formation of such phase therefore seems not to be thermodynamically favored, which may be a kinetic issue. Thus, the solid titration method by seeding biological apatite in SBF solution may simulate the effect of strontium in human body and help to understand why strontium-substituted apatite was formed as new bone.

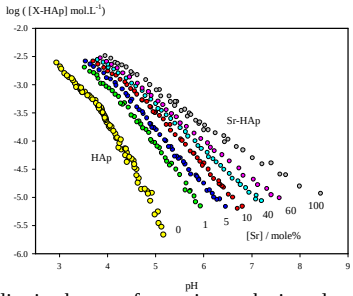

Fig. 1 Solubility isotherms of strontium-substituted apatite by solid titration method *(Acta Biomaterialia*, submitted)

OBJECTIVE:

To examine the effect of strontium to the stability of biological apatite in SBF solution with different strontium concentration by solid titration

MATERIALS AND METHODS:

Solid titration method was use to conduct the seeding experiment. ~1 mg biological apatite (rat bone; calcined at 600 ^{o}C to remove organic phase) was respectively added into 600 mL SBF solution containing different strontium concentration (0.05, 0.1, 0.5, 1, 5 mM), the solution was stirred by a magnetic bar at 37.0 ± 0.1 ^{o}C and monitored by a low-angle laser-scattering system, after 10d, the precipitates were separated by centrifugation and washed by 2-3 droplets deionized water twice, and dried at 50 ^{o}C over night. XRD, SEM, TEM and EDX were respectively used to analyze the precipitates.

RESULTS:

Biological apatite (rat bone) was characterized as fine carbonate apatite around 40 nm. After suspended in SBF for 10d, the crystal was found to grow preferred alignment of the *c*-axis. No appreciable difference of the precipitates was detected when strontium concentration below 0.1 mM in SBF solution (Fig. 2), the precipitate was only identified as carbonate apatite, where no strontium was detectable; however, significantly larger crystal was formed when strontium concentration raised to 0.5 mM, but crystal growth without preferred alignment, where strontium was detected in the precipitates (Fig. 2). In addition, more strontium was incorporated into crystal structure with the increase of strontium concentration in SBF solution, the phase was therefore identified as strontium-substituted apatite.

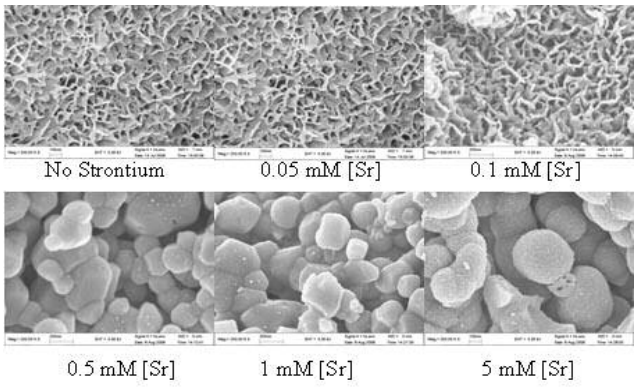

Fig. 2 Precipitates from SBF solution at 37 ^{o}C with different strontium concentration.

DISCUSSION:

SBF is a metastable solution, greatly supersaturated with respect to HAp, therefore the nucleation was driven by only adding 1 mg titrant as a seed. The growth of biological apatite in SBF solution was found to along *c*-axis, possibly due to the negative surface charge acting as a template for deposition of HAp in which the (002) plane had a preferred alignment, consistent with many observations *in vitro*. Meanwhile, strontium was found to play a key factor in the transformation of the mineral, because significant change of crystal was found when strontium concentration in SBF > 0.5 mM, although strontium-substituted apatite is much higher soluble than pure HAp according to previously reported, in particular, a Sr10-HAp was formed when [Sr] raised to 5 mM. Therefore, it is believed that the formation of strontium-substituted apatite is just a kinetic issue, although it is not a thermodynamically stable phase, it indeed nucleated easier, similar to octacalcium phosphate (OCP), although it is also not a stable phase, nucleating easier, therefore, OCP was normally detected in young bone, but gradually transforming to more stable phase HAp, thus seldom detected in mature bone.

CONCLUSION:

Biological apatite grows with preferred alignment. Strontium plays important role in the transformation of mineral. Higher dose of strontium intake was significantly benefit to the formation of strontium-substituted apatite due to nucleation much easier than pure HAp, thus it may be the template to the formation of new bone.

REFERENCES:

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