Salivary and Kidney Stones: Insights into Pathologic Biomineralization

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Introduction

Sialolithiasis is an obstructive stone formation, most commonly within the submandibular gland, affecting approximately 1 percent of individuals in the United States. The calculi are typically composed of calcium apatite, a compound found in Randall's plaque and phosphate predominant nephroliths. Here, we seek to correlate ultrastructural features, mineral density profiles, and energy dispersive X-ray (EDX) spectroscopy maps between sialoliths, Randall's plaque in the form of oxalate stones with phosphate stems, and phosphate renal calculi.

Methods

Intact submandibular salivary stones (n=5), calcium phosphate kidney stones (n=5), and calcium oxalate stones with an identifiable stem (n=5) were compared using light microscopy, scanning electron microscopy (SEM), and X-ray micro-computed tomography (Micro-XCT) techniques. EDX maps and ultrastructural features were compared to mineral density profiles for all stones.

Results

Sialoliths and phosphate kidney stones appeared to deposit in layers as visualized by light microscopy and micro CT (Figure 1, A, D, G). EDX confirmed a predominant composition of calcium and phosphorus for stone stems, sialoliths, and phosphate stones (Figure 2, A, C, E). Mineral density profiles were trimodal for all stone types (Figure 2, upper B, D, F) and ultrastructural features were similar across stone types at each density region: plates in lower density zones, spherulitic particles in medium density zones, and packed spheres in higher density zones. Patterns of Ca and P intensity by EDX matched mineral density profiles (Figure 2, lower B, D, F).

Conclusions

Calcium phosphate dispersion in urine and saliva appears to follow a common hierarchical archetype: spherulitic particles agglomerating in layer by layer apposition. Minerals varied in density but had similar elemental composition (Ca and P) in both secretory (salivary) and excretory (kidney) pathological biomineral masses.

Figure 1: Hierarchical Structure of Salivary, Phosphate, and Stem Stones

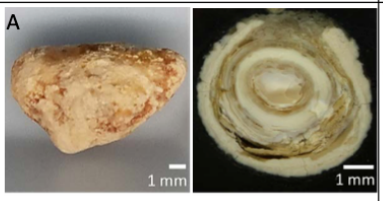
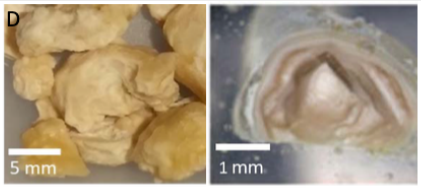
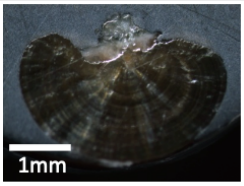
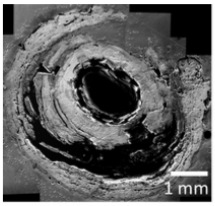
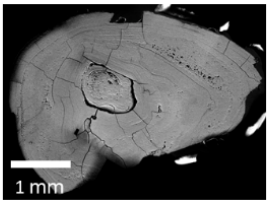
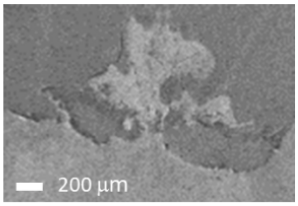
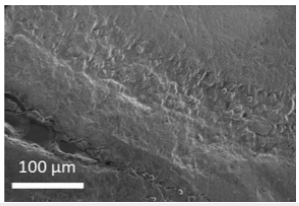
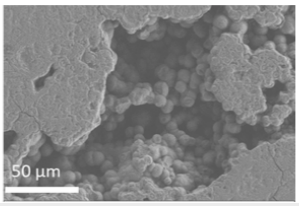
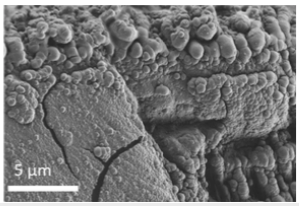
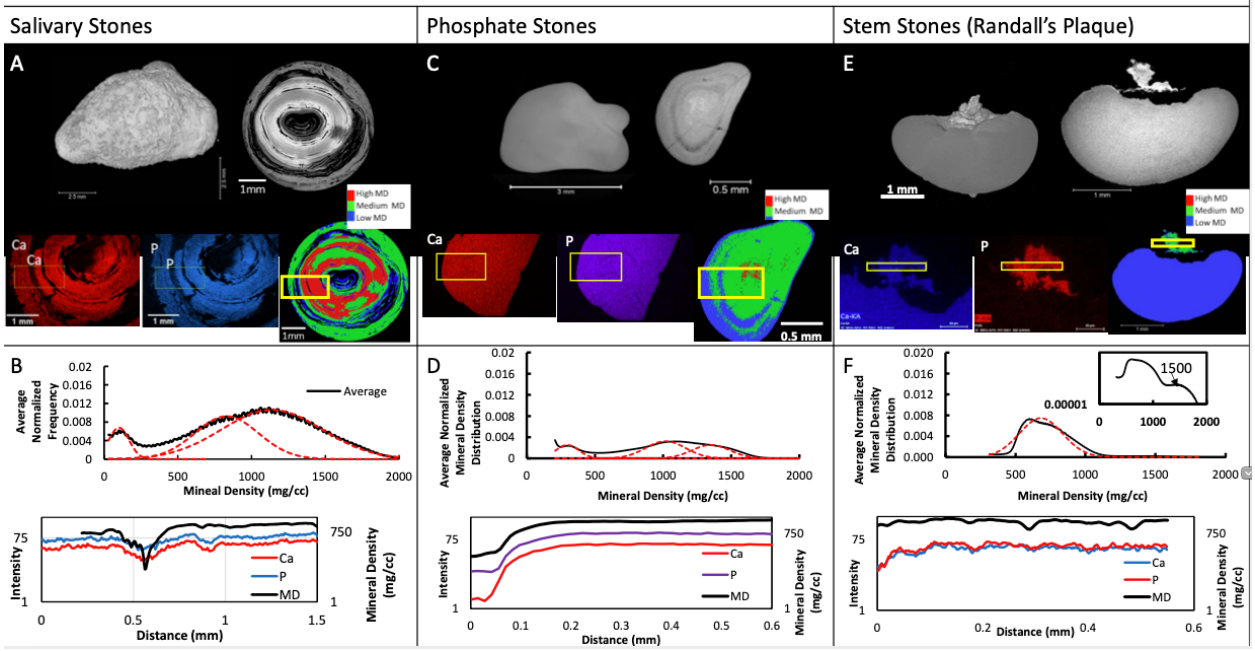
	Salivary Stones	Phosphate Stones	Stem Stones (Randall's Plaque)
Light Microscopy			
Electron Microscopy			
Electron Microscopy			

Figure 2: 3-Dimensional Features, Mineral Density, and Chemical Composition of Salivary Stones and Kidney Stones



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Introduction

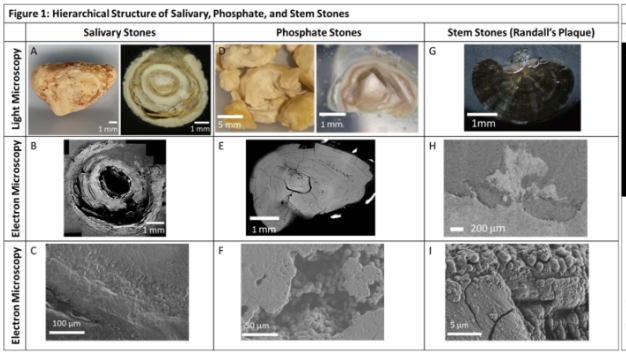
- Randall's plaque (RP), salivary stones, and calcium phosphate (CaP) based kidney stones are all predominantly composed of the same material.
- Patients with salivary stones are 4.74 fold more likely to have nephrolithiasis (Acta Otolaryngol. 2016; **136**: 497–500).

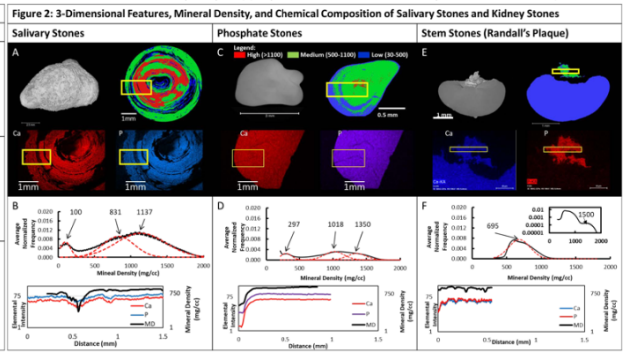
Objectives

To correlate Randall's plaque and calcium phosphate based kidney stones to salivary stones using multiple advanced imaging modalities.

Materials and Methods

- N = 5 salivary stones, N = 5 oxalate stones with RP stem, and CaP based kidney stones were used.
- **Correlative Imaging**: Light Microscope, Scanning Electron Microscope, X-ray micro-computed tomography (micro-CT), Energy Dispersive X-ray (EDX) mapping; Correlated mineral density and elemental maps





Results

- Sialoliths and CaP nephroliths showed layer-by-layer apposition (Figure 1, A, D, G)
- EDX confirmed CaP composition of RP, sialoliths, and CaP nephroliths (Figure 2, A, C, E).
- Mineral density (MD) profiles were trimodal (low, medium and high MDs, Fig 2, upper graphs B, D, F) for all stone types and ultrastructural features were similar across kidney and salivary stones (Fig 1 C, F, I); **Low**: plate-like formations; **Medium**: spherulitic particles; **High**: packed spheres.
- EDX based Ca and P were spatially correlated with micro-CT based MD profiles (Figure 2, lower graphs B, D, F).

Conclusions

Kidney and salivary stones follow a common hierarchical archetype suggesting a shared mechanistic process for biomineralization.

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