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Large Fibres in Urinary Calculi – Promoters of Stone Formation

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Summary. Large fibres (ϕ 10–20 μm, length up to 5,000 μm) are sometimes imbedded in urinary calculi. It may be that these fibres can catch sediment particles and promote stone growth. By scanning electron microscopy the morphology of the fibres was studied as well as the relationship of the fibres with crystalline stone components. The reported findings suggest that the fibres are possibly formed in the tubuli as the result of an hitherto unknown defect.

Key words: Urinary calculi, Fibres, Matrix, Fibre matrix, Stone growth, Stone fixation, Tubular defect.

In our last 700 stone analyses fibres attached to stone surfaces were observed in approximately 15% of the samples. The frequency of bundles of fibres in and between urinary calculi reached 3%. The fibres can be recognized with a simple magnifying glass, though higher magnifications, accomplished by SEM (scanning electron microscopy) are more suitable. It is surprising that the occurrence of these macroscopic fibres was not reported earlier. Bulky fibre aggregates were found with all types of crystalline stone material, i.e. oxalates, phosphates, urates and cystine. Besides this irregular masses of fibres without crystalline material were found in 4 cases. The fibres were radiologically invisible and were generally colourless. In one case a mass of crystallite-free fibres showed a brownish pigmentation suggestive of uric acid. All pictures presented here are made by SEM. The numbers in the scales refer to micrometers (1 μm = 10^{-3} mm). The composition of crystalline stone material, established by X-ray-diffraction, is summarized in Table 1.

Table 1. Mineral composition of calculi shown in Fig. 1 to 20

Figures	Composition
1 + 5 + 20	60% apatite, 30% whewellite, 10% weddellite
2	70% apatite, 30% whewellite
3	40% whewellite, 40% apatite, 20% struvite
4	90% whewellite, 5% weddellite, 5% apatite
6	60% whewellite, 35% apatite, 5% weddellite
7 + 8	80% struvite, 15% apatite, 5% weddellite
9–13 + 15 + 16 + 19	uncoated fibres
14 + 17 + 18	60% weddellite, 40% whewellite

Morphology of Fibres

Figures 1 and 2 show networks of fibres within kidney stones which were exposed after crushing in a mortar. The imprint of the pestel is visible in Fig. 1 (*arrow*). In these examples the presence of fibres was *not* distinguishable before grinding.

In other stones fragments of crystalline material are glued together by exposed fribres (Fig. 3) or a cluster of fibres is attached to a single stone particle (Fig. 4).

Uncoated fibres are demonstrated in Fig. 9 and, in more detail, in Figs. 10 to 19.

The coating of fibres by crystals can be seen in Figs. 5 to 8 and 20. The *arrow* in Fig. 6 indicates a breach in the coating of the gel-like substratum. Figure 20 shows in detail a heavily coated fibre. Partially coated fibre bundles are to be seen in Figs. 7 and 8, in the latter case the bundles were glued together with stone particles.

By comparison of morphological characteristics, the coated and uncoated fibres seem to be of the same material. The ultrastructure is, of course, better seen in the uncoated condition. With regard to cross-sections three main forms can be distinguished, labelled "a", "b", "c" in Fig. 10 (see also the skeleton, Fig. 21). Examples of these three forms can be found in other pictures too. Presumably the rather circular tube "a" is the basic structure; "b" and "c" can be derived from this by a loss of internal fluid.

Another feature is a spiral or coiled structure; in Figs. 11 and 12 the spirals marked by "d" are opened. Compare this also with "a" in Fig. 10 and other less pronounced exam-

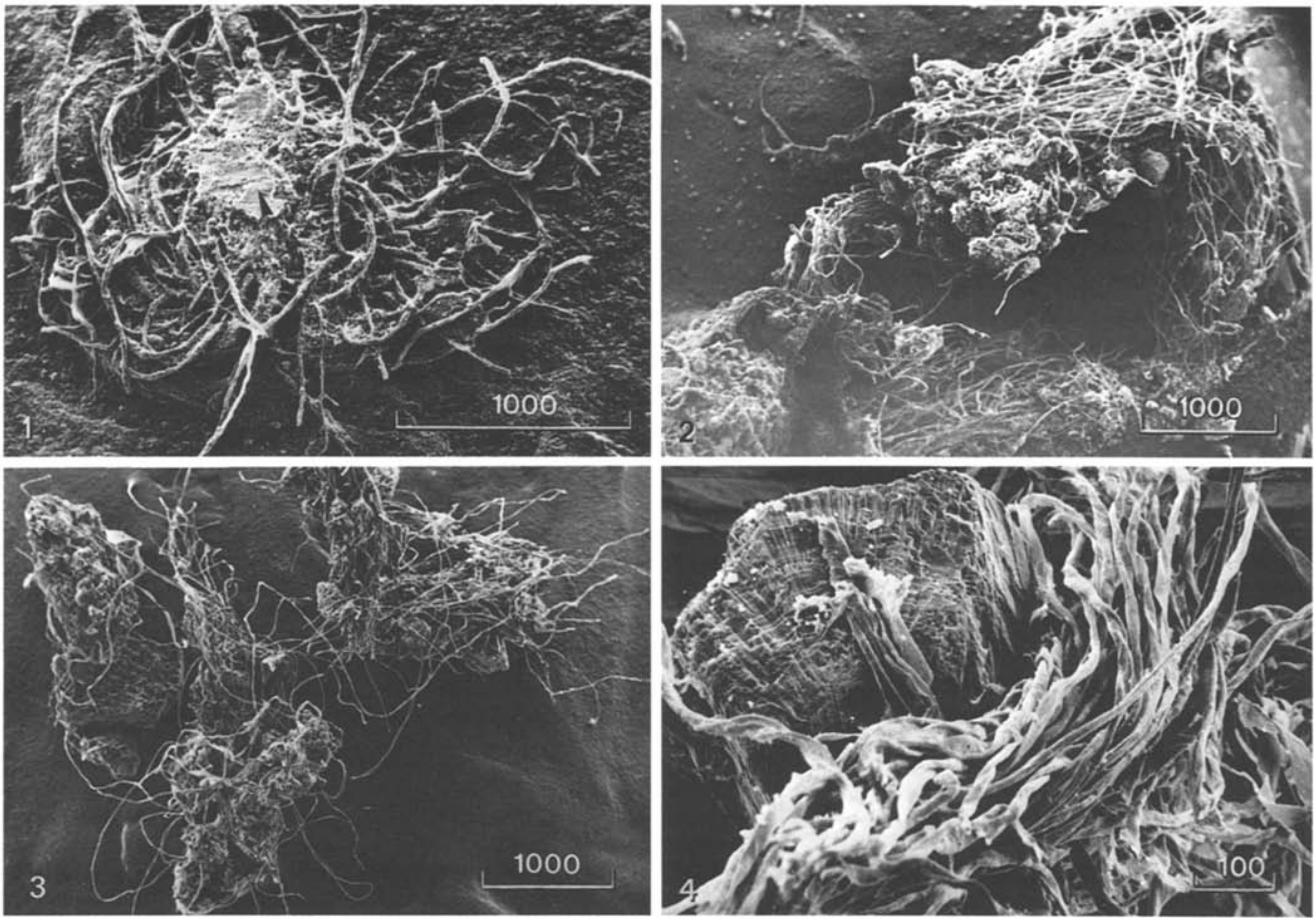
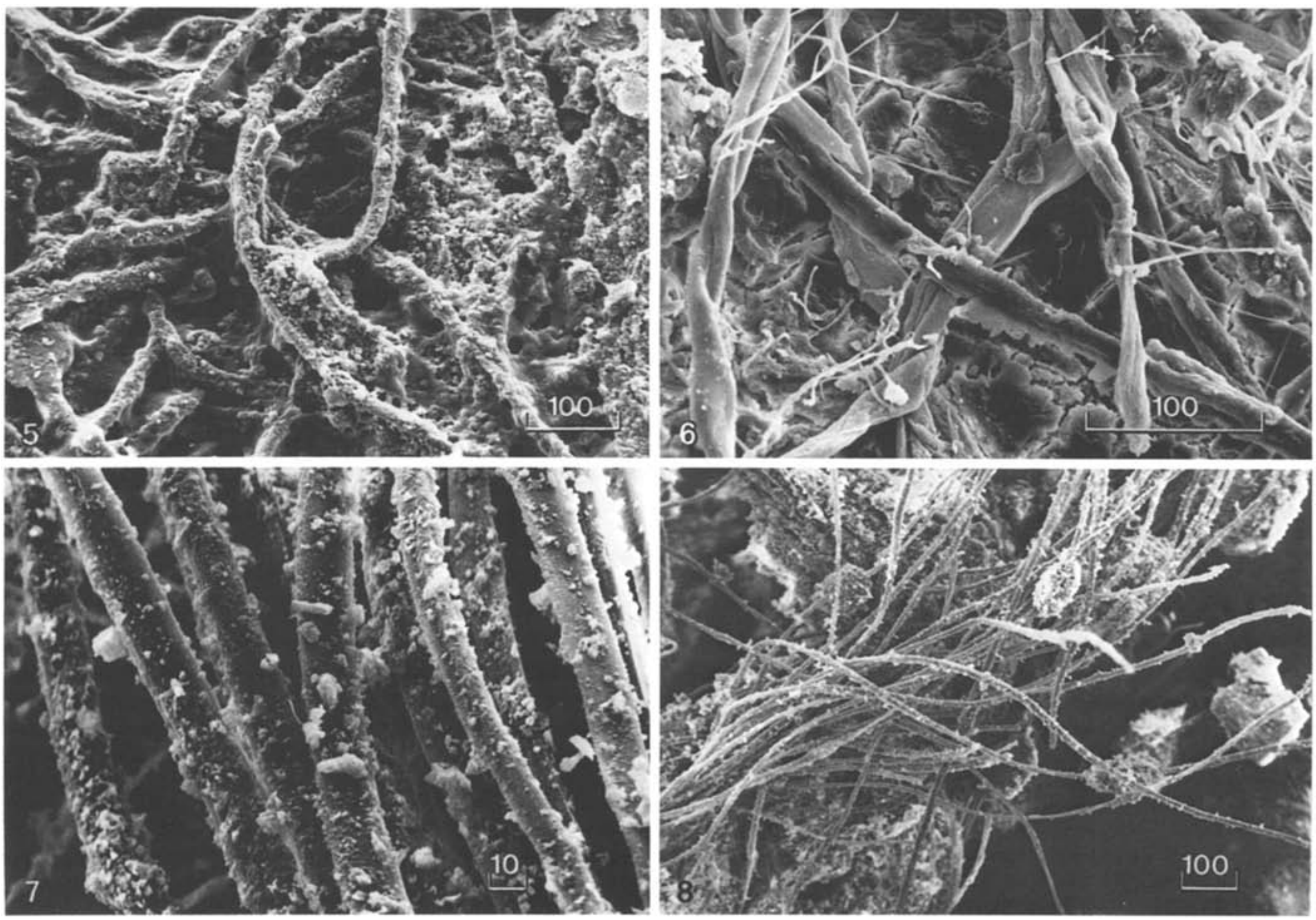


Fig. 1–4

Fig. 5–8



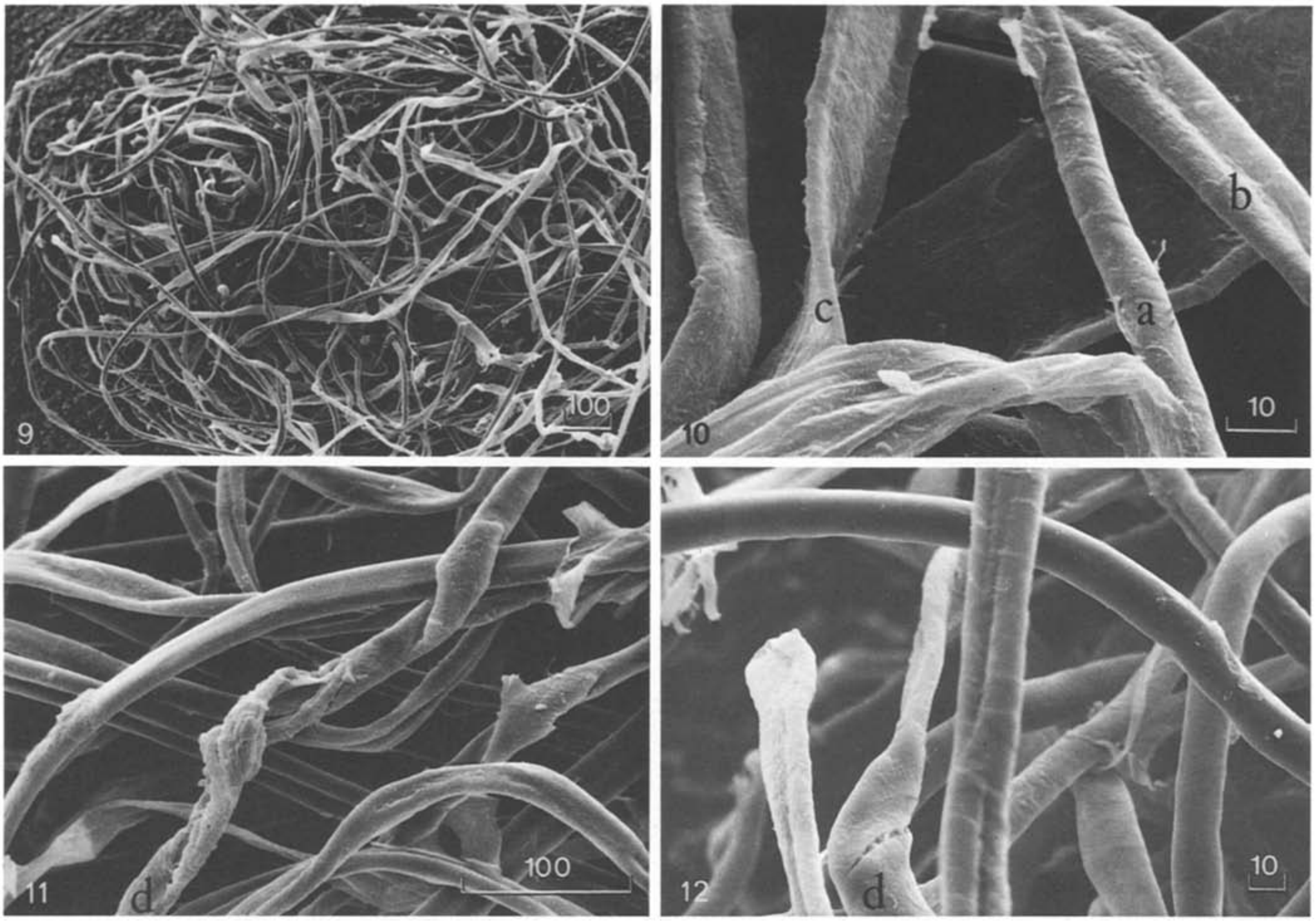


Fig. 9–12

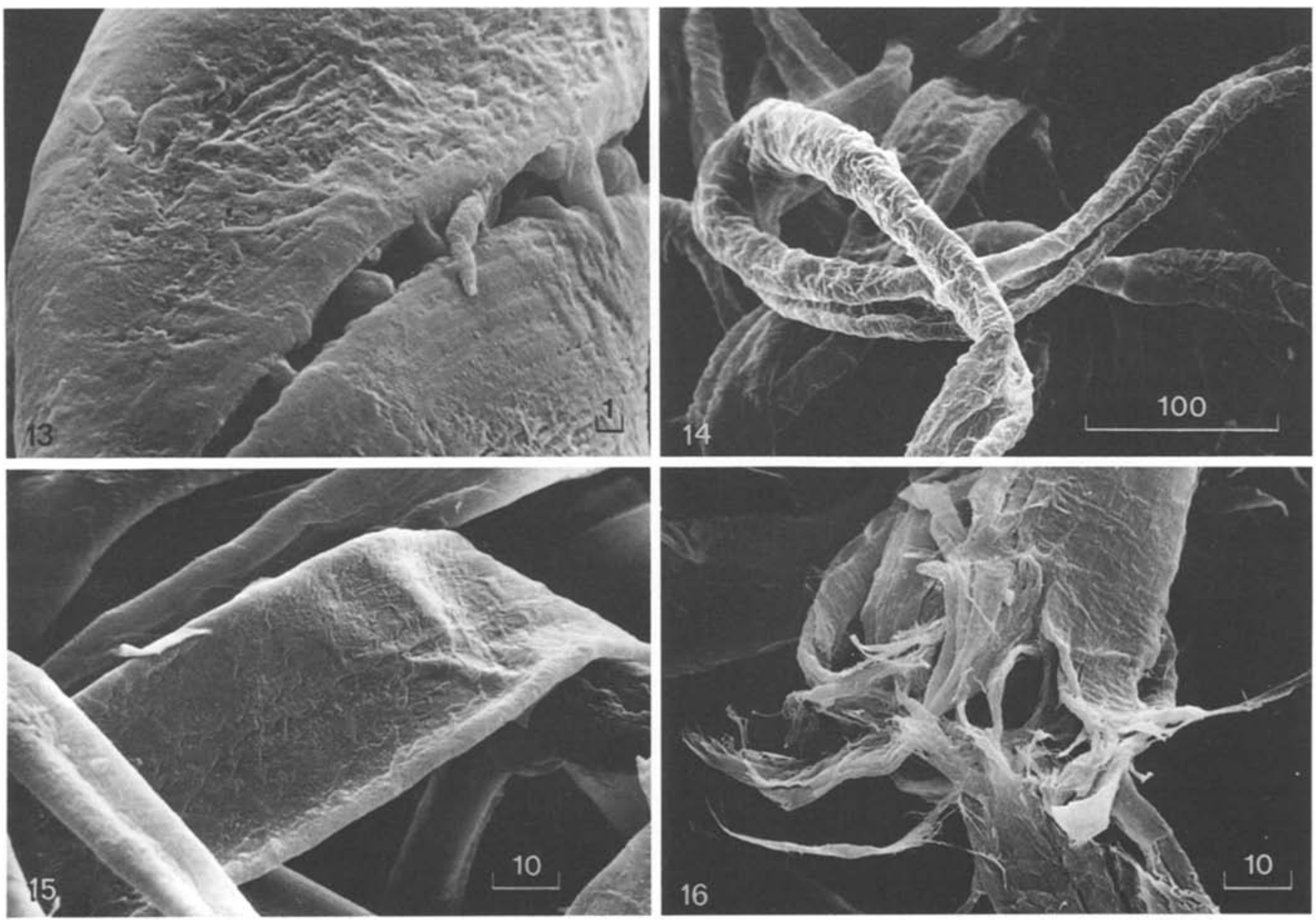


Fig. 13–16

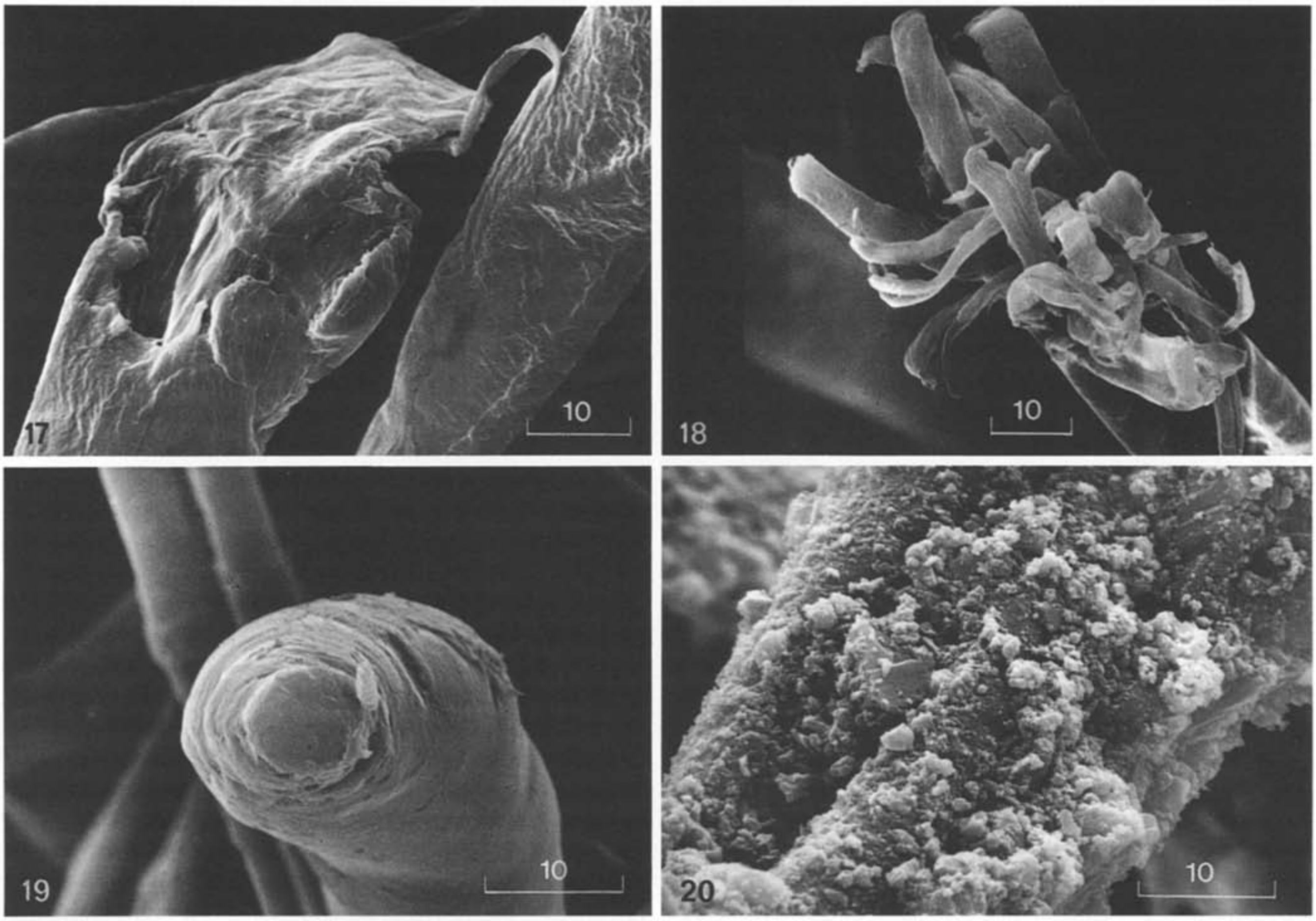


Fig. 17–20

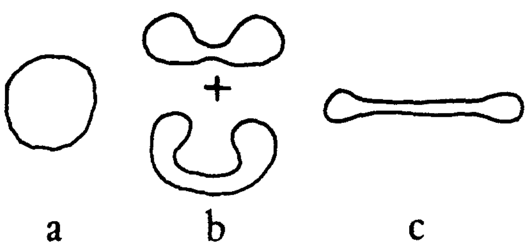


Fig. 21.

ples of spiral or segmented growth. Details of surfaces are presented in Figs. 13 ("a"), 14 ("b") and 15 ("c"). The diameters of the coatings in Figs. 13, 15 (protein material, no apatite present) are 0.2–0.6 μm. Crushed foils appear (Fig. 14) and fibres are split in to layers, Fig. 11 (*right*). The foil-formed nature of the fibres was clear in the end sections, Figs. 17 to 19 and also in the areas of fracture (Fig. 16) or of spiral openings ("d" in Fig. 11). The latter picture also demonstrates that the fibres are hollow.

Dimensions. In uncoated circular fibres most of the diameters are either between 17 ± 5 μm or 9 ± 3 μm. After coating, ∅ 30 ± 10 μm were found. The length of the fibres as can gathered from Fig. 9, and reached 1,000 to 5,000

Table 2. Nephrons, fibre matrix and urinary cast

Tubule Segment	Diameter (μm)	Length (μm)
1) Renal Tubular Dimensions (2)		
Proximal	50–65	1,700–2,400
Descending limb	14–22	0–1,400
Ascending limb	14–22	600–1,800
Distal convoluted	20–50	200– 900
Collecting duct	200	2,200
2) Fibre Matrix		
a) native	17 ± 5 and 9 ± 3	1,000–5,000
b) coated	30 ± 10	
3) Urinary Cast (4)		
Hyaline cylinders	ca. 18	50– 300
Granular casts	ca. 40	80– 600
Waxy casts	ca. 50	100– 400

μm (1–5 mm (!)), see Table 2. Therefore the ratio length: with (60...550) is much larger than with the urinary casts (3...17), Table 2. The diameters of both hyaline cylinders and our fibres are comparable and in accordance with the inner diameters of tubuli.

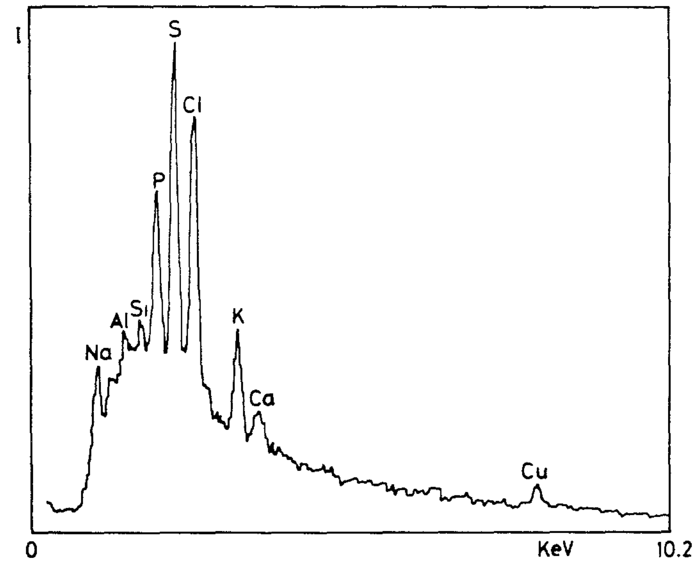


Fig. 22.

Matrix Function of Fibres

If a mass of fibres was lodged in the urinary tract (compare Fig. 9). It might capture sediment particles like a sieve and fix them causing further stone growth. The sample, Fig. 9, was voided spontaneously without any signs of secondary crystallisation. In our examples, Fig. 1 and 2, the fibres occurred first and the stone formation was the second step, thus the fibres might act as a "Fibre matrix". In the example, Fig. 3, crystalline material are only glued together by fibres.

To emphasize the possible role of fibre aggregates in the process of stone formation, I have called this phenomenon "fibre matrix" [1]. But this term might lead to confusion with regard to the former use of the term "matrix". It must be stressed that the fibres described have nothing to do with mucoproteins, formerly called "stone matrix", which is present in all urinary stones at an averadge of 2.5 weight-%. There is also no similarity with the "fibrous matrix", described by Malek and Boyce [5] nor with the uromucoid which Hallson and Rose [3] described following quick evaporation of urine.

The behaviour of these fibres can be regarded dynamically; Uncoated fibres may be voided before any stone-forming process is initiated. In comparison with the prompt sieve-effect in presence of urinary sediment the intimate coating of the fibres is a time consuming process, i.e., as with tissue, it is not easily achieved. Presumably the loss of buoyancy of the young fibres by catching denser crystalline material is the crucial step in the stone forming process. If this happens, the fibres can act by promoting the stone growth *and* by fixation of the concrement in the urinary tract.

EdS-Analyses

The analysis of the organic material of the fibres is not complete. Besides protein sulfur, KCl and/or NaCl were detected within all fibres at a level of 1% by weight, (Fig. 22). This was done with EdS (energy dispersive spectrometer – as part of the SEM-system for analysis of elements with atomic numbers larger than 9 (fluorine)). The trace elements Al, Si, Cu were always present, in a few samples together with Zn and Fe. The appearance of the soluble alkali chlorides in an urinary product is inexpliable.

At present it is unknown where and how the fibres are formed. The diameters (Table 2) suggest (a) that the fibres could be produced in the tubuli, (b) that they are probably proteins or mucoproteins and (c) that soluble halides are essential components. From assumptions (a) to (c), a mechanism can be suggested which is based on two effects:

Higher concentrations (ionic strength) of Cl^-, K^+, Na^+ in distinct regions of the tubuli could produce a salting out effect on soluble proteins. Protein material could be transformed into foils in this way. If they coat the inner walls of the tubuli, the diffusion of halide-ions, enclosed in the cylindric shaped foild against the tubuli walls would be hindered. In this case the ions promote an osmotic pressure: water moves inwards and inflates the cylinders. If the cylinders rotate in their longitudinal axes in the course of their distal movement, the coiled structure, "d" in Fig. 11, could be explained.

If our assumption that the fibres are formed in the tubuli can be verified a serious defect might be present. The explanation of the genesis and nature of the fibres need further study.

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