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Preparation and characterization of Kidney stone phantom with its flexural strength studies

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Abstract : Kidney stone phantoms were prepared using commercially available material called Begostone. Prepared stone types were characterized using X-Ray Diffraction(XRD) and Fourier Transform Infrared Spectroscopy (FTIR). Characterization results provides the structural properties and particular functional groups.Flexural strength analysis were done in an Universal Testing Machine (UTM). This study will help in optimizing the treatment parameters of shockwave lithotripsy and other similar non-invasive techniques.
Keywords: stone phantom, Begostone, functional groups, flexural strength, shockwave lithotripsy.

1 Introduction

Kidney stone formation is very general these days. The kidney stones are composed essentially of crystalline skeleton and noncrystalline materials as well. Major crystalline components include calcium oxalate, calcium phosphate, uric acid and xanthine. Most stones contain only one or two crystalline components that account for almost 95% of stone weight and noncrystalline components include protein, cellular debris, and other organic materials[2].Despite the rapid spread of endourology and extra corporeal lithotripsy, studies of destruction of urinary calculi by extra corporeal fragmentation procedures point to the lack of fundamental data on the mechanical properties of urinary calculi like stone fragility and the factors that may influence them[1].Natural kidney stones are of various compositions and each composition requires different optimum treatment parameters. None of the natural kidney stone found in the body has a specific composition. The natural kidney stones found have a mixture of various compositions. Also the structure of such natural kidney stone is irregular. Because of the difference in chemical composition and structural features of stones, the efficacy of stone fragmentation may vary significantly. In the present study, the prepared kidney stone phantoms were characterized using XRD and FTIR analysis for their functional groups. Based on these date we can optimize the lithotripsy treatment which is already in use.

2 Experimental Details

Among various commercially available materials, Begostone was used for mimicking the original kidney stones. Based of the varying composition of water and begostone five different stone types were prepared. ASTM standard moulds were used for these phantoms.

2.1 Preparation of phantoms

To prepare kidney stone phantom begostone plus, distilled water and albumen was mixed uniformly. Mixing the above three in a particular ratio produced a particular type of stone phantom. In this way five different types of stone samples were produced by mixing the above three materials in five specific composition.[Table 1]After five different types of stone phantoms were prepared, they were filled in mould. After the stone had acquired the proper shape by keeping the prepared stone in mould for nearly 24 hours, the prepared stone phantom were taken out.The stone phantom obtained was with the dimension 75 mm* 10 mm *10 mm. The phantom obtained was slowly heated to 90℃ and held at this temperature for 12 hours to polymerize the albumen[3].[Fig 1]

Table 1: Composition Of Different Kidney Stone Phantom

Stone Type	Begostone(%)	Water(%)	Albumem(%)
Oxalate	82	15.5	2.5
Cystine	73	24.5	2.5
MAPH/CA	66	31.5	2.5
CHPD	81	16.5	2.5
UA	72	25.5	2.5

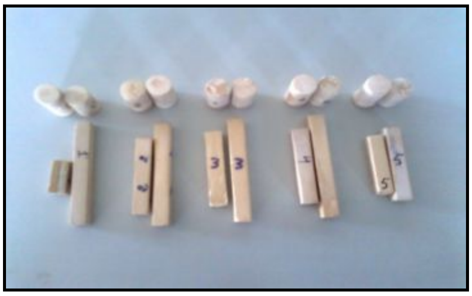


Fig 1: Various kidney stone phantoms

2.2 XRD & FTIR analysis

Five samples were of the five different types stone phantom .For XRD studies each sample to be investigated was crushed into a fine powder and sprinkled onto a grease-smeared glass slide. A diffraction scan was obtained in the range 12˚ to 80˚ [°2Th.] using a PANalytical Model X'pert PRO X-ray diffractometer with Cu-Kα radiation (of wave length 1.54060 Å) to analyze their crystalline structure. For FTIR the powdered samples was investigated for the specific functional groups.Infrared (IR) spectra were recorded in the wave number range 4000-400cm^{-1} using Thermo Nicolet Model AVATAR 330 Spectrometer.

2.3 Flexural strength studies

Flexural strength of the sample was studied using Universal Testing Machine(UTM) Tinius olsen, Model H5KN,UK with 50 N load cell for three point flexural tests while 5 KN load cell.[Fig 2].

Fig 2: Universal Testing Machine

3 Results and Discussion

Figure 3 and 4 shows the XRD and FTIR spectrum of the stone phantom types. The XRD data shows that the samples are crystalline in nature. The IR spectrum shows various frequencies of vibrational modes. Each mode characterizes particular functional group identified from IR correlation chart. Figure 4 shows the comparison curves on the flexural strength various stone phantoms at span length of 60 mm and 30mm. Table 2 shows the flexural strength of various stone types at two different span lengths.

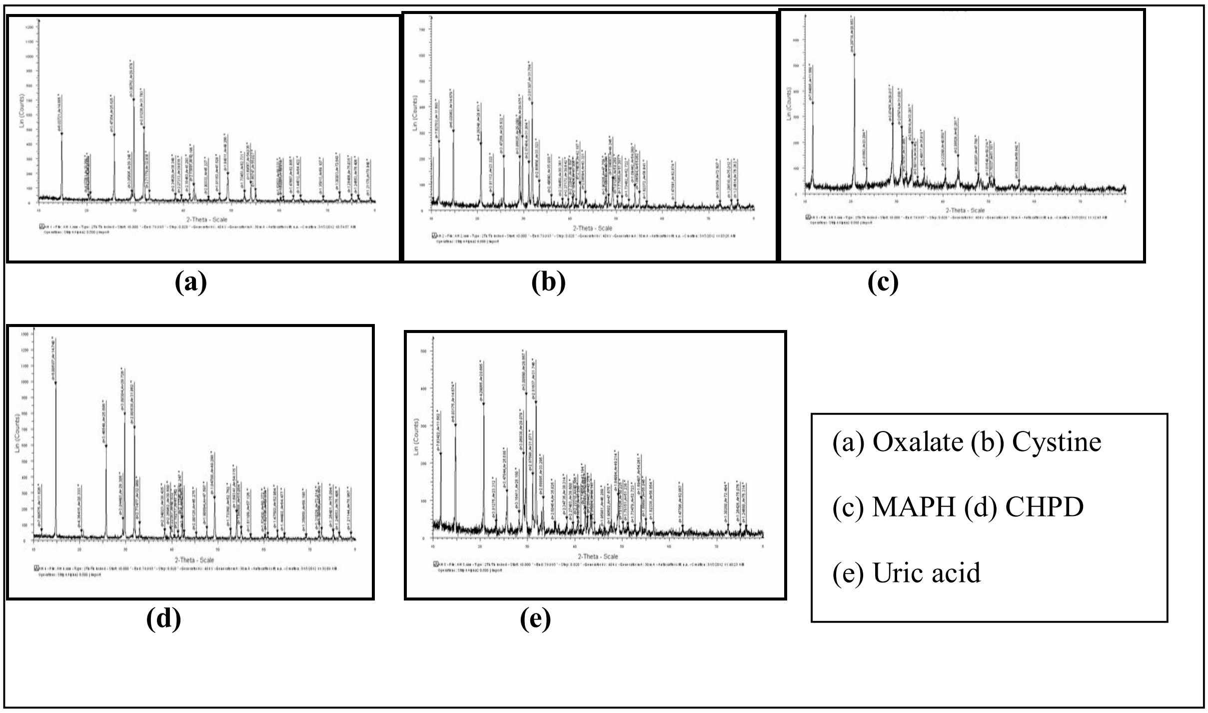


Fig 3: XRD pattern of various kidney stone phantoms

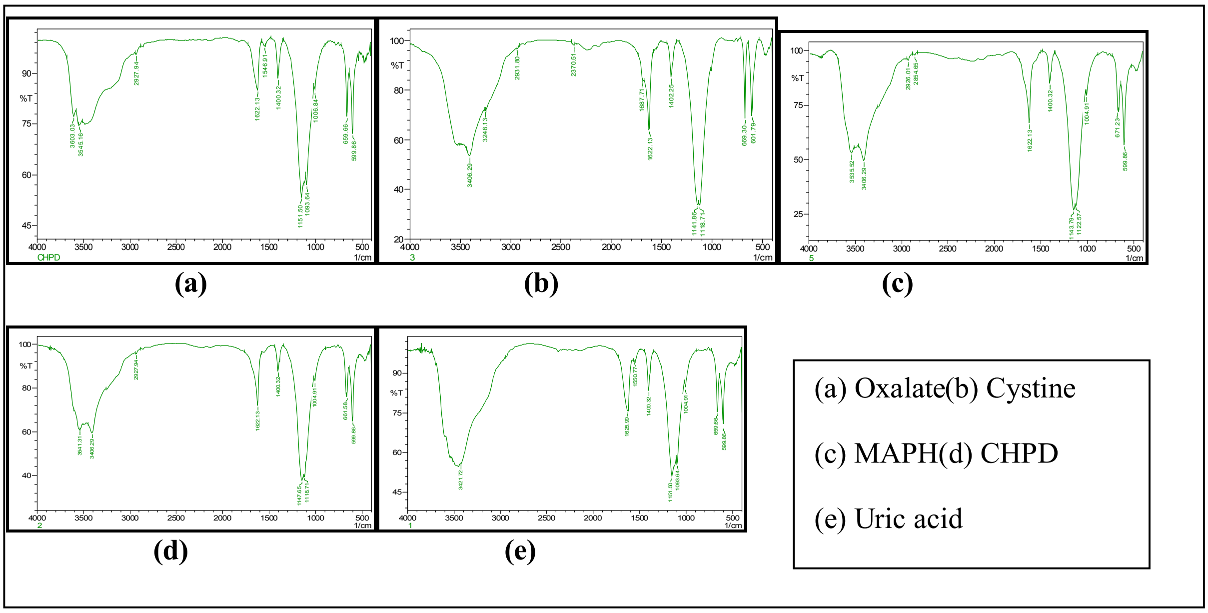
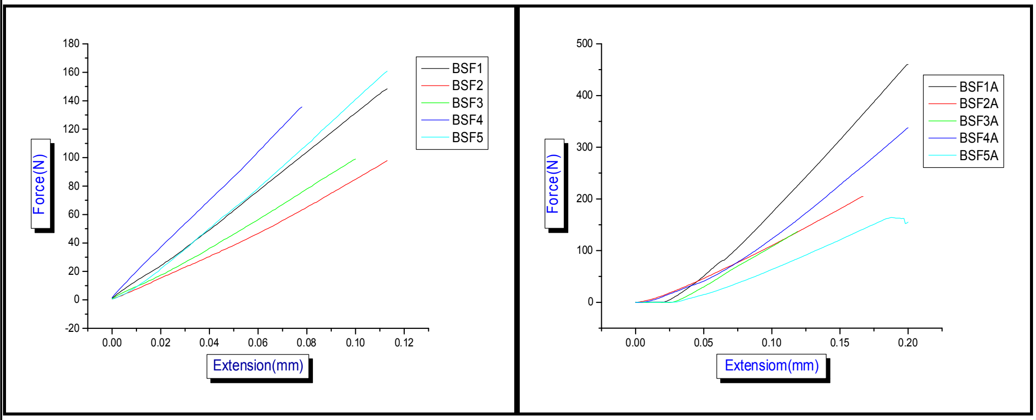


Fig 4: IR spectrum of various kidney stone phantoms

Table 2: Flexural strength data for different span lengths of various kidney stone phantoms

Kidney stone phantom	Flexural strength(MPa)	
	30 mm span length	60 mm span length
oxalate	20.70	13.35
CHPD	19.28	12.21
Cystine	14.32	11.69
Uric acid(UA)	13.52	9.65
MAPH/CA	10.33	8.91



(a) **(b)**

Fig 4: Comapritive curves of Flexural strength analysis on various kidney stone phantoms at 60mm span length indicated as BSF1-5 (b) 30mm span length indicated as BSF (1-5)A[BSF1-Oxalate,BSF2-Cystine,BSF3-MAPH/CA, BSF4-CHPD, BSF5-UA]

3.1 Interpretation of XRD data

All natural kidney stones contain a few percent of insoluble complex organicmatter that is primarily protein, embedded in a number of different inorganic materials. Existing kidney stone phantomsdo not contain insoluble organic material in combination withan inorganic matrix. The inorganic component of the presentcomposite phantom stones was BegoStone Plus, which isessentially a strengthened gypsum plaster. The stone phantom was hard enough and insoluble so that it can be used in variety of lithotripsy applications.

3.2 Interpretation of FTIR spectrum

From the FTIR spectra, it was observed that there was no substantial difference in their spectrum at the different stages of preparation and hence it was assumed that there was no change in the chemical composition of the material used till their formation as artificial stone.

3.3 Interpretation of Flexural strength data

The maximum flexural strength was found for oxalate and minimum was found for MAPH/CA.The sequence of the flexural strength is as following:

Oxalate > CHPD > Cystine > Uric acid > MAPH

It was also found that by decreasing the span length for each model during testing, the flexural strength increased. This showed that force required to break the sample was more for stone phantoms with smaller span length. However the order of flexural strength remained same with oxalate having maximum flexural strength and MAPH/CA having minimum flexural strength.

4 Conclusions

The composition of the stones under study were confirmed by comparing the FTIR, X-ray diffractionThe X-ray diffraction analysis confirmed their crystalline nature. The FTIR spectra analysis of the artificially prepared stones showed the conformity with their basic chemical substance. It was also observed that there was no substantial difference in their spectra at the different stages of their preparation and hence it was assumed that there was no change in the chemical composition of the materials used till their formation as artificial stones.For the first time the flexural strength for the artificial kidney phantoms were studied directly using universal testing machine.It has been observed that the flexural properties depend on the span length used by the UTM machine even foe the samples cut from a single stone. . It has been observed that decreasing the span length of the sample increased the flexural strength of the same sample. The flexural strength was maximum for oxalate and minimum for MAPH/CA and was in the same order as the tensile strength. BegoStone appears to providea reliable and consistent phantom material for SWLresearch.The new inorganic/organic composite kidney stone phantomsdescribed here can be produced with both mechanical andacoustic properties that mimic the range of these propertiesmeasured for human renal calculi. These ternary compositekidney stone phantoms should have wide utility in a varietyof lithotripsy studies.

References

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