DIAGNOSTIC MEASUREMENTS OF HUMAN BONE AFFECTED BY PRIMARY GONARTHROSIS

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Abstract: - The aims of the paper is to furnish a new methodology to (i) define chemical and physical parameters used as references to distinguish between a healthy human bone tissue and the one affected by primary gonarthrosis and (ii) to enrich the base of knowledge used in the biomaterials field. The methodology pointed out is based on measurement techniques used for civil engineering materials. Therefore, it is possible to assess that the obtained results depend only by the material under test and not by the specific measurement method.
Experimental results will be shown (i) to assess the suitability of the characterization method pointed out, and (ii) to allow the definition of parameters to evaluate the primary gonarthrosis diseases in human knees.

Key-Words: - primary gonarthrosis, characterization, thermal analysis.

1 Introduction

Gonarthrosis is a degenerative condition of knee joint with chronic and progressive course most frequently defined as changes involving articular cartilage damage (Fig.1), abnormal bone formation, reactive changes in synovial membrane and pathologic synovial fluid [1].
Knee arthrosis is the most common type of arthrosis [2]-[4]. Arthrosis can be primary and secondary. Pathogesis of primary degenerative changes in articular cartilage is based on loss of proteoglycans and decomposition of collagen skeleton of intracellular matter. In addition there is also

Fig.1 The loss of cartilage results in increasing stiffening and deformation of the joint [7].

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"material fatigue" [5]-[6].

The site of initial damage remains unknown. It is known presently that in the development of the process, reparative reaction of chondrocytes expressed by increase of synthesis of the main collagen types (type II, in lower degree types IX, VI, XI) and also of proteoglycans, is the primary event, at cell level [1]. The final result of the pathological process in gonarthrosis is imbalance between synthesis of articular cartilage and damage leading to its loss. Each cause or process inducing cartilage degradation exerts effects on the occurrence and progression of gonarthrosis. Gonarthrosis is diagnosed on the basis of clinical and radiological examinations. Magnetic resonance, bone scintigraphy and arthroscopy are also of importance.

In the paper objective measurement method to detect knee bone affected by gonarthrosis is presented [8],[9]. It is based on the application of the Thermo gravimetric (TG), Differential Thermo gravimetric (DTG) and Differential Scanning Calorimetry (DSC) analysis to some milligram of knee bone. These analysis are well known and deeply applied for engineering materials [10]-[12]. The main advantages are: the use of well-known techniques permits to assess the traceability and the objectivity of the measurements; the use of reduced quantity of bone permits to be executed in ambulatory.

2 Materials and Methods

Experimental tests are executed on bone samples with weight in the range 22-30 mg extracted by healthy knee and knees affected by primary gonarthrosis and furnished by GIGMA, MARAN and AILEIO. The measurement system pointed out is composed by: NETZSCH STA 409 controlled by PC by using serial connection. The experimental conditions are the follows: (i) reference: 20mg of Coalino Calcinato , (ii) flow speed: 15ml/min, (iii) environment: air, (iv) temperature step: 10°C/min, (v) initial temperature 20°C, (vi) final temperature 800°C. NETZSCH STA 409 permits to evaluate at the same time both TG DTG and DSC. The advantage is the possibility to easily compare the three curves by assuming same environmental conditions.

It is worth to remark that the value of the peaks depends on the balance that in the case of STA 409 has resolution 2µg. However, the peak values strongly depends from the experimental conditions and for this reason have no significance in the analysis. This justify why the thermo-gravimetric curves can be plotted on the same figure with arbitrary scale on y axes. As concerning the temperature where the peak occurs, they are evaluated with a thermocouple with an accuracy of 0.2 °C [13].

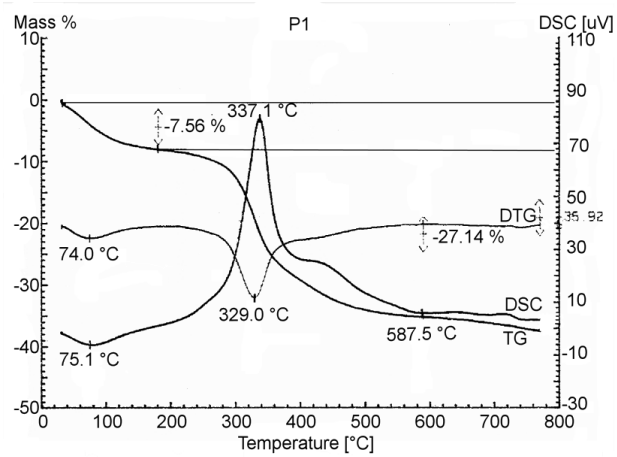

Fig.2 Thermogram of a healthy human knee

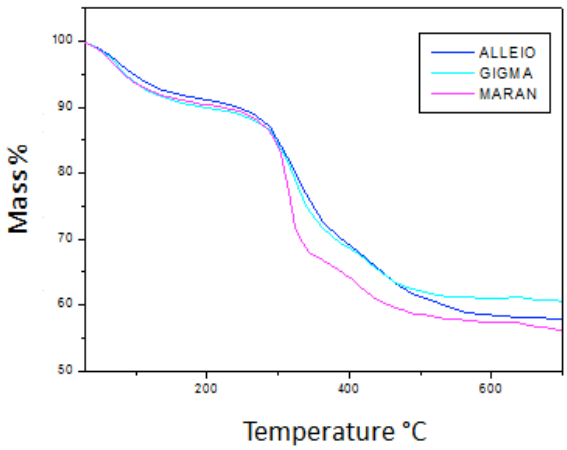

Fig.3 TG Curves of samples of bone affected by primary gonartrosis.

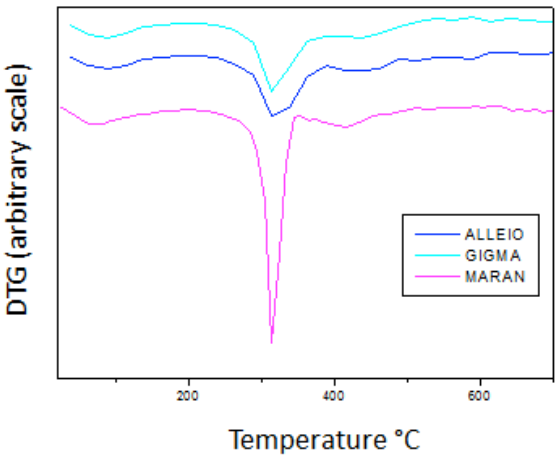

Fig.4 DTG Curves of samples of bone affected by primary gonartrosis.

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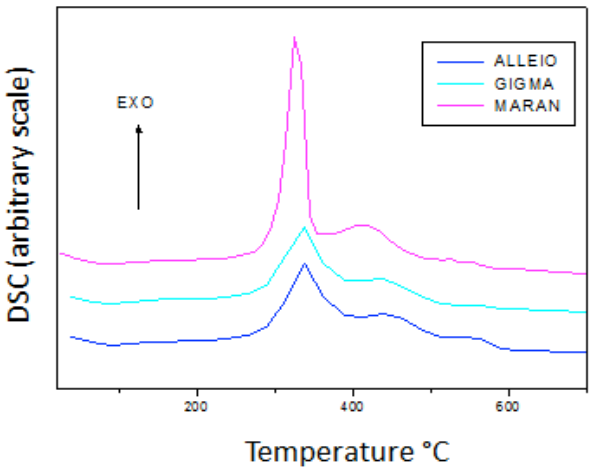

Fig.5 DSC Curves of samples of bone affected by primary gonartrosis.

3 Experimental Results

Fig. 2 shows the TG the DTG and the DSC [8] of human healthy metatarsal head. These curves are used as reference to compare the same curves obtained by samples extracted from bones affected by hallux valgus disease.

Fig.3 shows the TG curves of bones affected by primary gonarthrosis. TG curve allows to evaluate the percentage of sample weight loss respect to the temperature. Thermo-gravimetric profiles highlight that the MARAN sample losses more weight respect the others.

Fig.4 shows the DTG curves of the samples. In the curves there are 4 peaks corresponding in the TG at the temperature where there are weight loss.
Fig.5 shows DSC curves where can be highlighted the endothermic peak corresponding to the water loss (at about 100°C), and exothermic peaks corresponding to the loss of organic matrix.

Tab.1 DSC peak temperatures

Sample	Age	Temp water loss (ENDO) (°C)	Temp I peak EXO (°C)	Temp II peak EXO (°C)	Temp III peak EXO (°C)
HEALTY	/	75,1	337,1	440,0	/
GIGMA	60	87,9	333,6	432,6	540,3
MARAN	64	81,5	324,5	419,9	523,4
ALLEIO	71	90,1	338,0	438,0	541,0

Tab.2 TG values

Sample	Age	H2O loss (%)	Organic loss I peak (%)	Organic loss I peak (%)	Organic loss I peak (%)	Total loss (%)
HEALTY	/	7,56	27,14	/	/	34,7
GIGMA	60	10,01	20,81	5,71	3,86	40,39
MARAN	64	9,66	20,13	5,37	3,78	38,94
AILEIO	71	8,87	18,55	9,08	4,11	40,61

The water loss may provoke a first change in the protein molecules. After that, the organic components decomposition and burning start. Indeed, the second peak (at about 340°C) is generated by the decomposition of the organic matrix of the bone. The peak at about 420°C is generated by the degradation of residual organic material. The fourth exothermic peak at 520°C is generated by the degradation of the bone matrix.

The different trend and slopes of these curves respect to an healthy bone, may indicate the presence of the primary gonarthrosis. Indeed the last peack is not present in the healty bone curves, then the degradation of the bone matrix may be related to the degeneration of the matrix, effect of the illness on the bone, confirming the recent literature [1],[2]

In table 1 are reported the temperature values where the DSC peaks occurs.

Table 2 shows the TG values.
By comparing TG and DSC values, the samples affected by more severe intensity is ALLEIO. This hypothesis could be validated by the fact that at 520°C there is a higher weight loss respect to the other samples.

However the main results of this preliminary results is that in the case of bone affected by illness there are 3 exothermic peaks instead of 2. Due to the fact that the third peak occur after 100°C, this result can be easily observed also with measurement instruments less accurate and expensive respect to NETZSCH STA 409. Those instruments can equip ambulatories and hospitals and are able to furnish in few minutes information on the presence of the gonarthrosis by analysing few grams of bone, that can be obtained in local anaesthesia with a biopsy.

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4 Conclusion

In the paper is presented a new possible diagnostic measurement methods to characterize bone tissues extracted by human knees. The proposed methodology is based on measurement methods, and instrumentations typically applied to study civil engineering materials. The proper combination of well-known measurement techniques and commercial measurement instruments allow assessing the traceability of the measurement. Experimental tests are executing by performing the thermal analysis of samples extracted by healthy knee bone, and the ones affected by primary gonarthrosis furnished by GIGMA, MARAN and AILEIO. The experimental results highlight a different behavior of the healthy human bone tissue respect to the one affected by primary gonarthrosis disease. In particular, the exothermic peak at about 520 °C could be an intrinsic characteristic of the disease, since in the sample of healthy bone tissue, this peak is not present.

The presence of this third exothermic peak can be easily detected also with measurement instruments less accurate than the NETZSCH STA 409, and can be used as discriminant to distinguish between healthy bones and the ones affected by primary gonarthrosis.

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