Preparation and improvement of Thermal Expansion Coefficient and Impact Strength of (PMMA\CaAl2O4) system

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Abstract-- In this research, a biocompatible polymer system was developed with the body of the organism supported by a two-phase ceramic powder consisting of a mixture of calcium oxides and alumina powder. Samples were obtained using a fluid mixing method and using ultrasound technology to distribute the powder and spread it within the polymer (PMMA). The weight fraction used for reinforcement was (0%, 1%, 2%, 3% and 4%). The thermodynamic analysis technique (TMA) was used to complete and test the thermal expansion coefficient for a certain temperature range between 20-250 ° C where the results showed a significant improvement in thermal expansion coefficient at temperatures below 100 ° C for prepared composites at 3%wt. compared with that of the unsupported polymer showed a significant expansion at the same temperature range. Impact strength have measured by using Charpy test for all samples with a standard dimension of 5.5cm x 1cmx1cm. The pendulum angle was stabilized at 150 °, where all the prepared composite showed high impact strength ,hardness and fracture toughness, respectively, compared with the polymer material. The tested powder was tested using x-ray diffraction as well as the scanning electron microscopy and x-ray dispersion spectrometry to determine the ratios and interacting compounds in the preparation of biochemical powder.

Keywords: Biocompatible Polymer, Bioceramic, Thermal Expansion Coefficient and Impact Strength.

1. Introduction

Polymer-based composites are promising materials that have been of interest to researchers and practitioners from the last century. Where many researchers were interested in using in industrial applications, especially the structures of vehicles, space ships and spare parts for many electronic devices and equipment because of their ease of manufacture and light weight in addition to the price of licenses[1]. In terms of medical applications, researchers have been interested in this field, and their properties have been developed and improved in line with the application or purpose for which they were designed [2]. These polymer-based compounds have been developed in the medical field after the introduction of new biologically compatible materials with the tissues of the organism's body and is consistent with its members. Bio- Materials are essential materials in this field because they are harmless to the health and compatible with the part to be replaced in terms of performance and aesthetic [3]. This polymeric material in the axis of our research is (PMMA). Which is characterized by light weight and good mechanical properties and non-toxic and low cost of its formation is not stable in its dimensions after the formation and this feature is desirable by stimulating researchers in this area of finding appropriate solutions in the disposal of this problem by adding materials improved and stable in the dimensions and can maintain the Polymer shrinkage and contraction [4]. Biomedical material is a great material when used as a compensatory material for damaged bones or teeth, damaged or damaged, having characteristics very similar to the organism's bone in terms of shape, hardness, durability and high corrosion resistance [5,6] The term bioceramic is called a substance that is

synthetically compatible with the human organism and is non-toxic and can integrate fully with the body organs and cells can grow in it [7,8] Calcium and phosphorus compounds are considered to be essential substances in this field, since human bones constitute 75% of these substances, as well as other substances of no less importance [9,10].Bioceramic such as: MgO, ZnO, CaO, glass ceramic, TiO2, HA, ZrO2, Al2O3 [11,12]. The aim of this work is to prepare and synthesize a bio-polymer mix supported by a tissue-compatible ceramic material that can be integrated with the bones and fixed dimensions after its formation.

2. Experimental Part:

In this study, calcium oxides from egg shells were used after several chemical and physiological processes and treatments. Alumina powder (42 nm) is also used and has a surface area of 50 g per square meter and from a US facility. The ceramic powder was prepared using powder technology and using active mechanical mixture for 8 hours to ensure a homogeneous sample with 1: 1 calcium oxide and alumina, 37% and 63%, respectively. SEM image with EDx Spectrum and X-Ray diffraction used to powders test. The base material, the biocompatible PMMA polymer, was used with the body's tissue with its solvent, the cold chlorophorme (MMA). (0% - 4%) with the use of the liquid mixing method and with the help of ultrasound to increase the distribution and homogeneous spread of the powder within the matrix of the base material to ensure the success of the tests required for this work.

The coefficients of thermal expansion and stability in the dimensions due to the difference in temperatures have been investigated by technique of thermodynamic analysis or so-called Thermal Mechanical Analysis (TMA) [13]. The linear expansion coefficient can be calculated using the equation:

$$\alpha=\frac{1}{L_{\circ}}\frac{AL}{A\dagger}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

(α): coefficient of linear thermal expansion

Original Length (Meters) L0:

Change in length to temperature change : $\frac{AL}{AT}$

The impact strength for samples can be calculated from the following equations [14]:

γ= MR (Cos ψ - Cos φ) ..... (2)

I.S = γ /A… ..... (3)

Where γ is fracture energy (Joule) , I.S is Impact strength (KJ \ m2) ,MR is pendulum energy=75J in this work and A is cross section area of sample.

The Vickers hardness (Hv), elastic modulus(E),yield strength(Y) and fracture toughness(K) for all samples have computed according to the following equations

Hv=1854.4(F/d2) ..... (4)

Where (F) is the applied load and (d) is diagonal length of the indentation.

E=81.9635 Hv .....(5)

Y=Hv/3 ..... (6)

K=(E*I.S)1/2 .....(7)

3. Results and Discussion

The morphology of the prepared CaAl2O4 nanoparticles has determined by scanning electron microscope (SEM) as shown in Fig.(1).The elemental analysis of prepared compound was carried out by EDX, as shown in Fig.(2).Through Fig.(3) the crystalline phase and crystallite size were determined

by powder XRD analysis. Effect adding of CaAl2O4 with weight fractions (1-4)% on the mechanical properties of PMMA are illustrated by Fig.(4-6).The Fig.(4) showed increasing of hardness and impact strength with increasing filler content. We also observed increasing in elastic modulus and yield strength due to present increased fillers as shown in Fig.(5).The fracture toughness of composite was increased with filler increased, moreover, the glass transition temperatures are increased with increasing wt.% of fillers except for concentration 1%. The table (1) shows linear thermal expansion coefficients (α) of samples as a functions of the weight fraction for (CaAl2O4) at various temperatures which obtained by practical results for test TMA shown in Figs.(7-11).We observe the composite with 3% wt. has the lowest linear expansion coefficient at all temperatures. The samples begin with simple expansion at room temperatures or precisely (20 ° C), but they showed rapid expansion at temperatures above 40°C with different thermal expansion for each sample .We notice a clear and grate decrease in the thermal expansion of composite with 3%wt. compared to the other samples where α=0.28x10-6K-1 at temperature 200C as shown in the table (1) . This is due to the high stability and the large resistance of the fillers. The shapes show that all samples drop down and reduce the thermal expansion after 60 ° C, but with varying degrees. The composites with filler (CaAl2O4) for all concentrations is highly stable compared to the matrix material and this is consistent with the source(14). The Figs. (7-11) show the practical test using the TMA technique where the patterns show the differential behavior of samples with change in length relative to temperature change for (20-250°C) and that the results obtained from them are reliable in choosing the most stable sample in the applications of teeth and dental fillings so this test was used for this purpose.

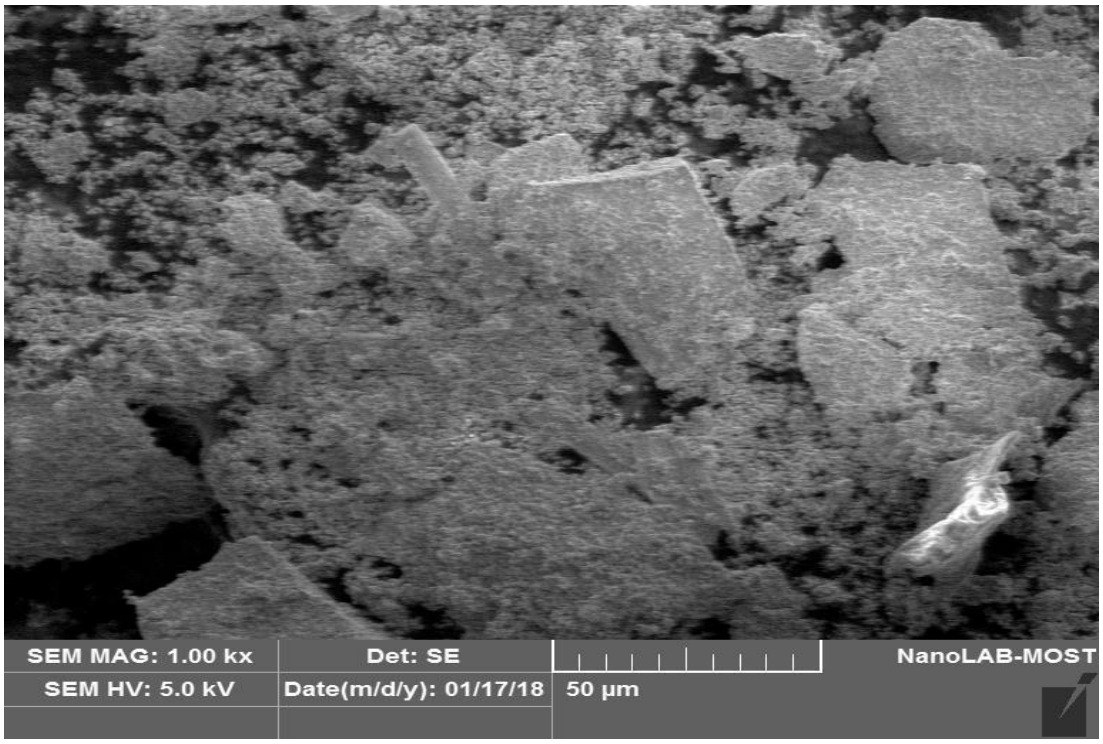


Fig: 1: SEM image of $CaAl_2O_4$ Nano-Powder.

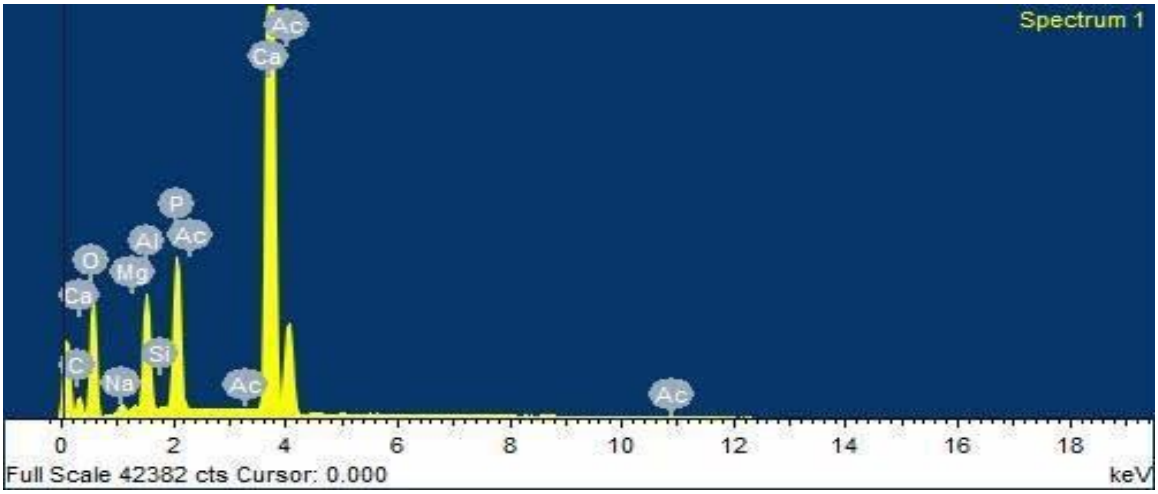


Fig:2: EDx- Spectrum of $CaAl_2O_4$ Nano-Powde

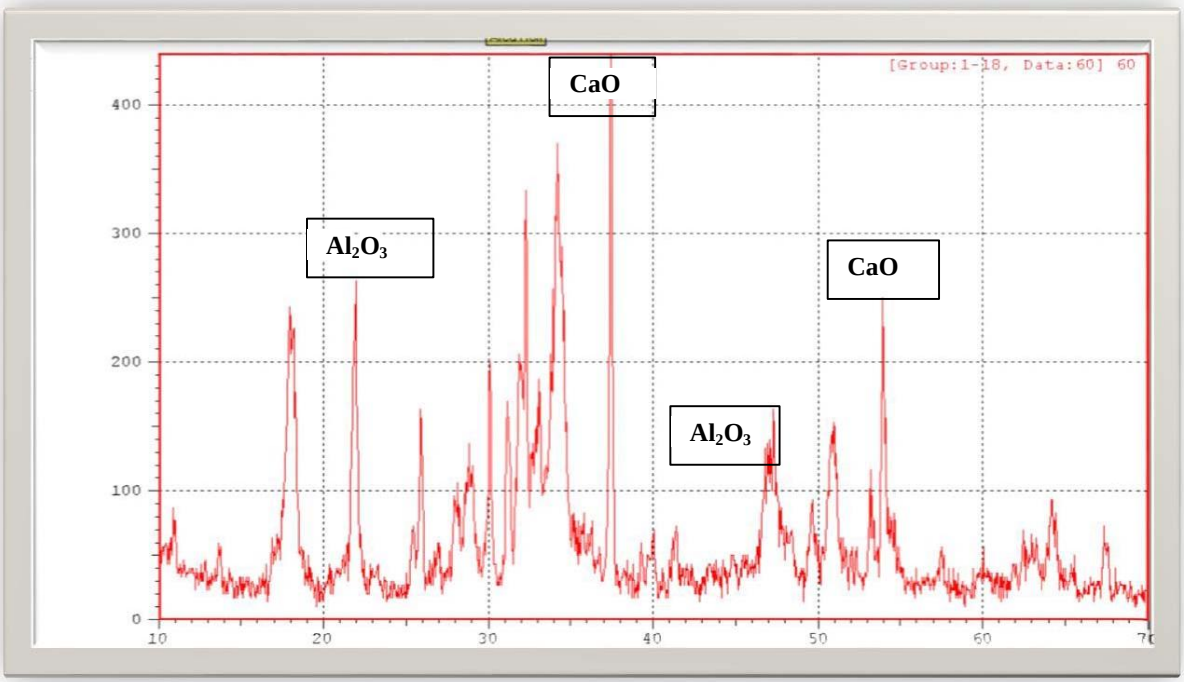


Fig:3: X- Ray diffraction of $CaAl_2O_4$ Nano – Powder

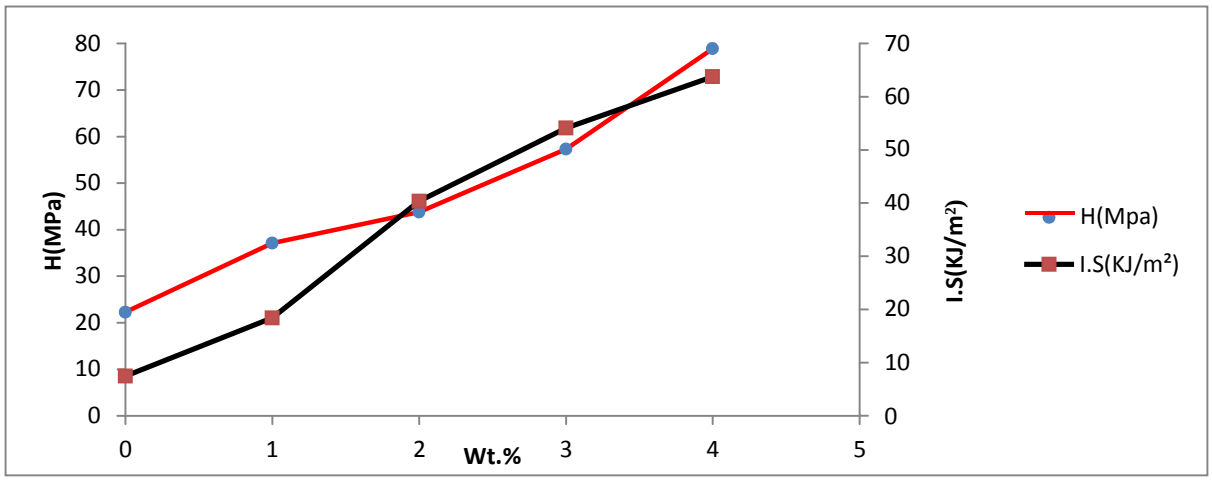


Fig (4).The hardness (H) and impact strength (I.S) as functions of weight fraction for ($CaAl_2O_4$).

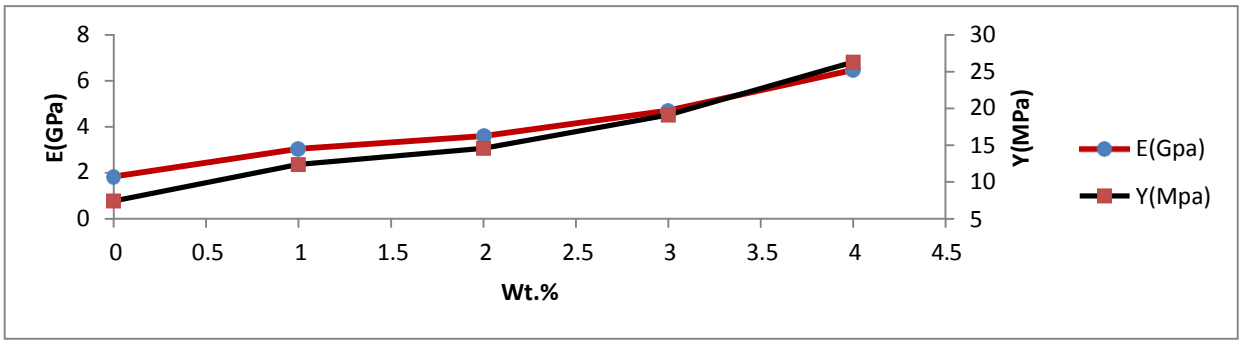
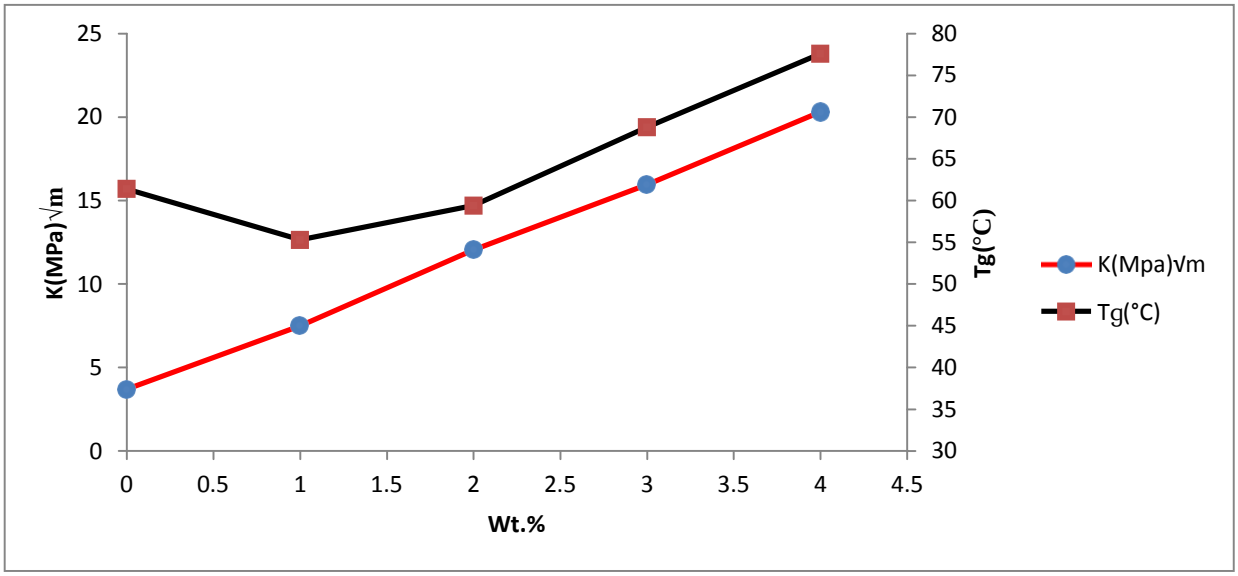


Fig (5).The elastic modulus (E) and yield strength (Y) as functions of weight fraction for ($CaAl_2O_4$).



Fig(6): Fracture toughness (K) and glass temperature (T_g) as a functions of weight fraction for ($CaAl_2O_4$).

Table (1): Coefficient of linear thermal expansion(α) as a function of the weight fraction for ($CaAl_2O_4$) at various temperatures.

Sample	α x10^{-6}/K T=20^{0}C	α x10^{-6}/K T=30^{0}C	α x10^{-6}/K T=40^{0}C	α x10^{-6}/K T=50^{0}C	α x10^{-6}/K T=60^{0}C
0	49.62	64.80	77.42	89.27	94.23
1%	17.26	54.85	73.96	85.19	87.95
2%	45.26	62.05	76.56	86.54	89.77
3%	0.28	0.72	0.79	0.50	0.43
4%	59.71	72.93	78.55	84.40	90.32

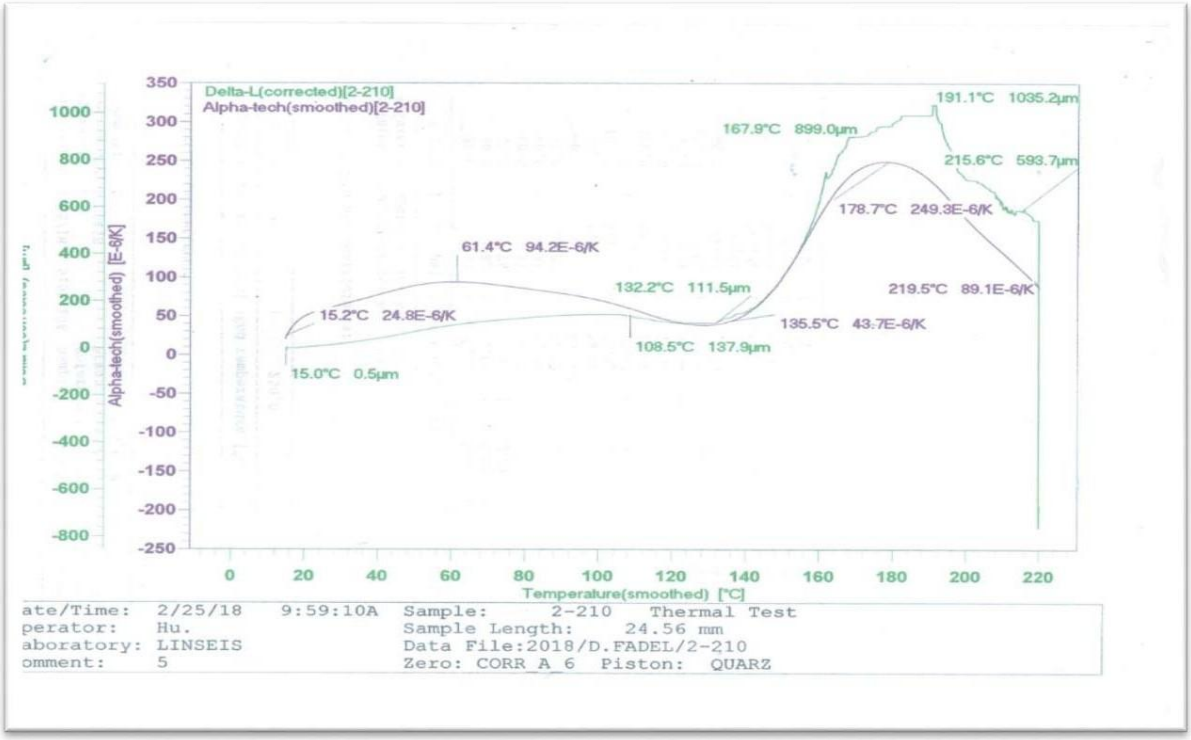


Fig (7).TMA for pmma.

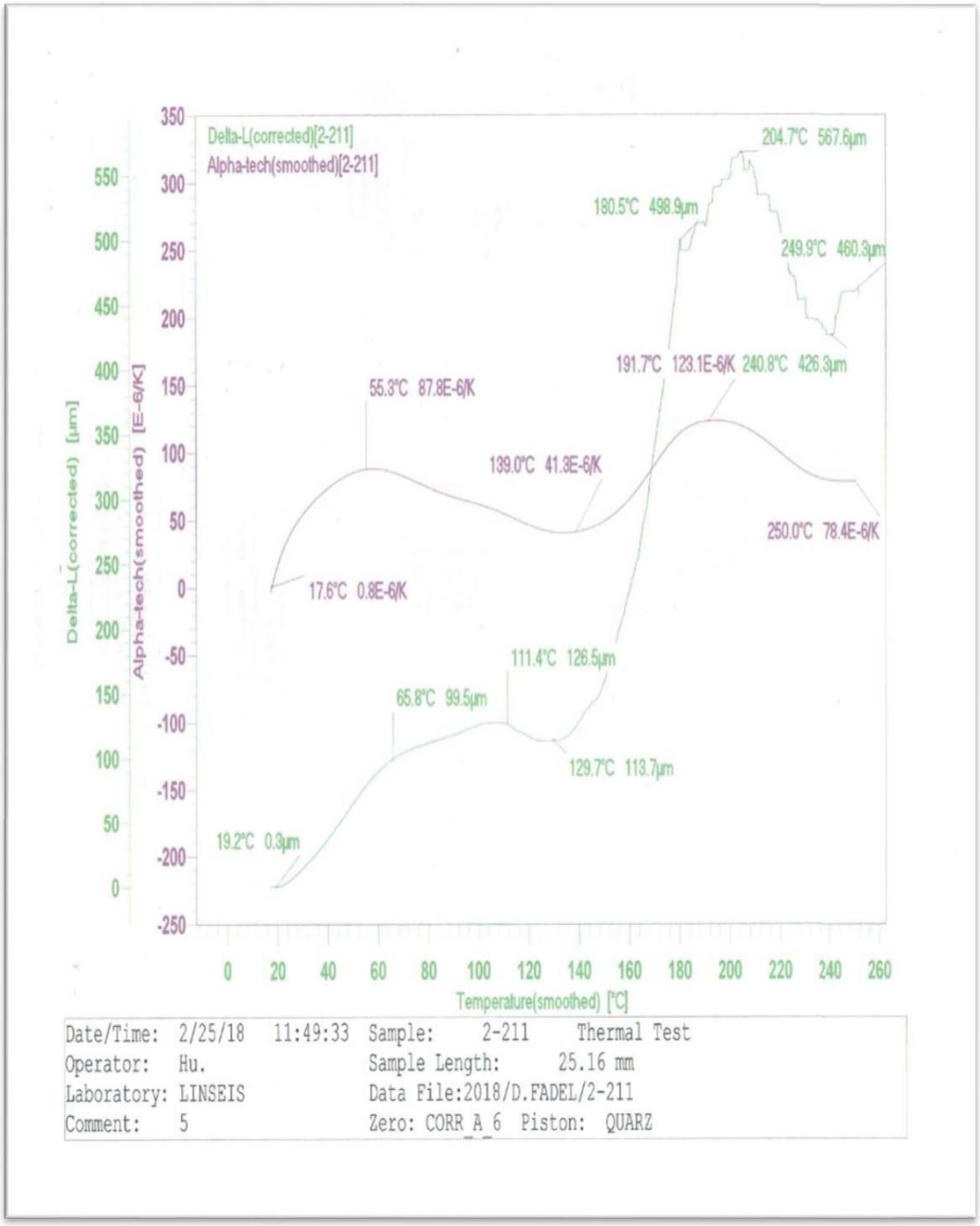


Fig (8).TMA for 1%wt.$CaAl_2O_4$.

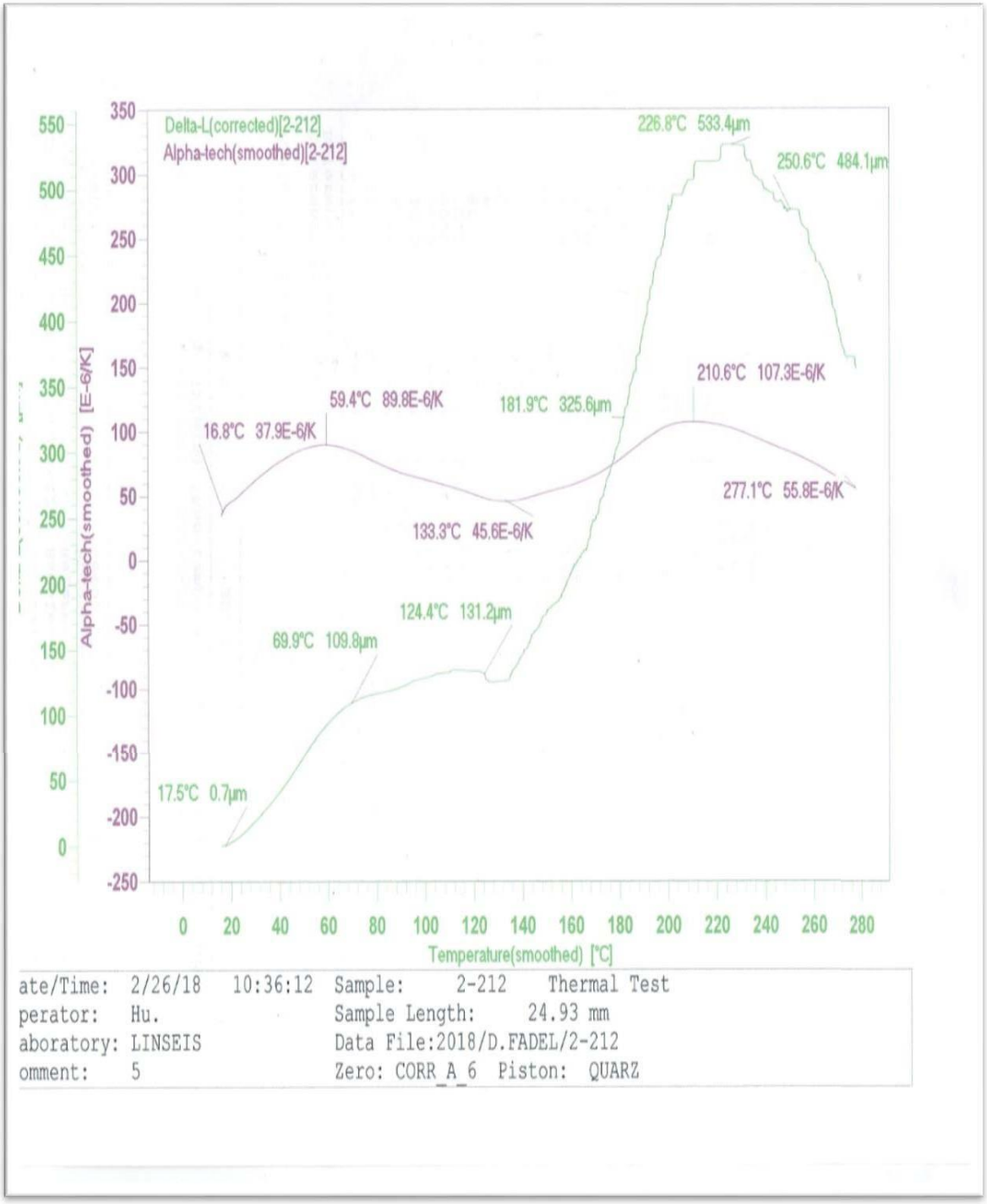


Fig (9). TMA for 2%wt.$CaAl_2O_4$.

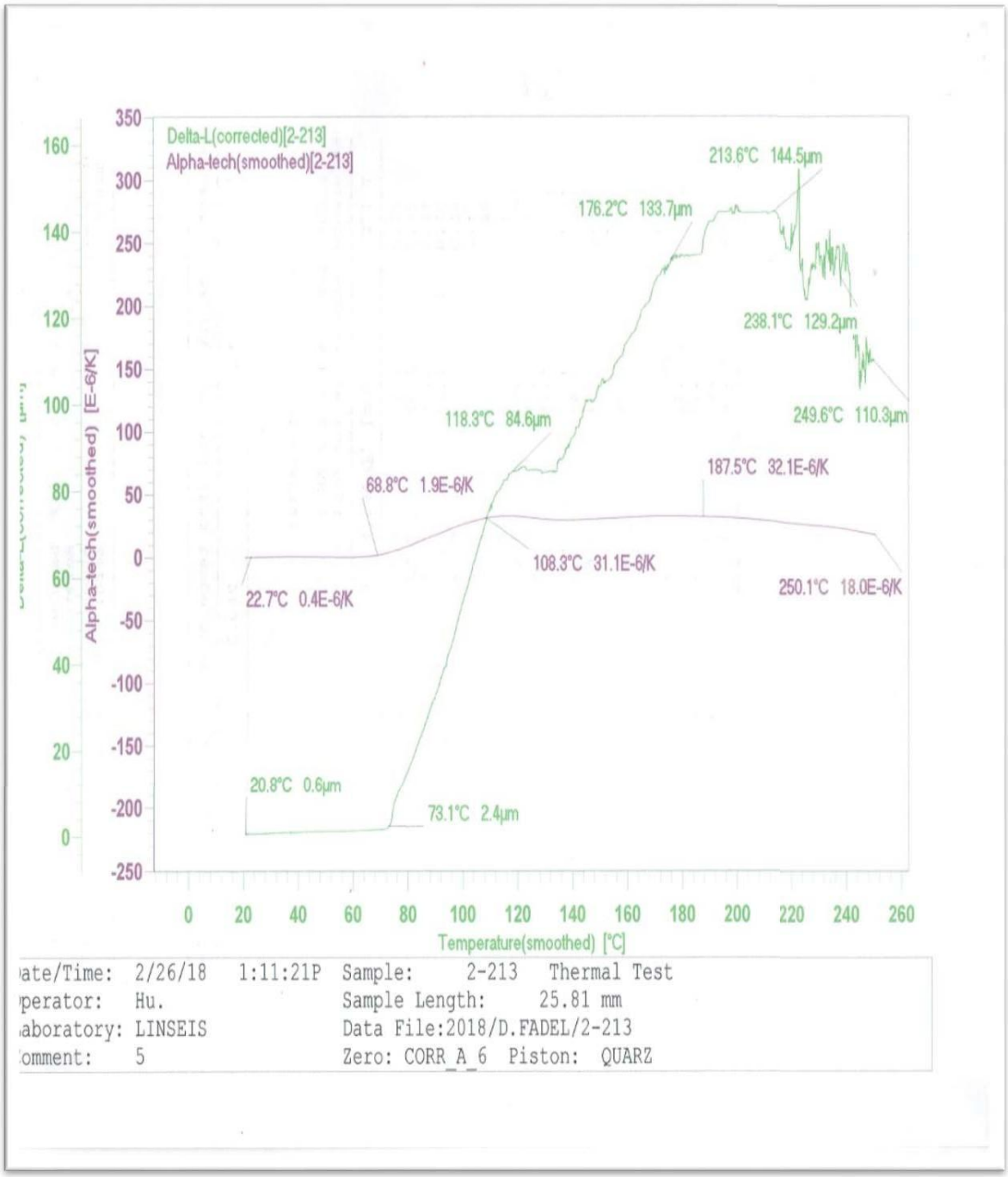


Fig (10). TMA for 3%wt.$CaAl_2O_4$.

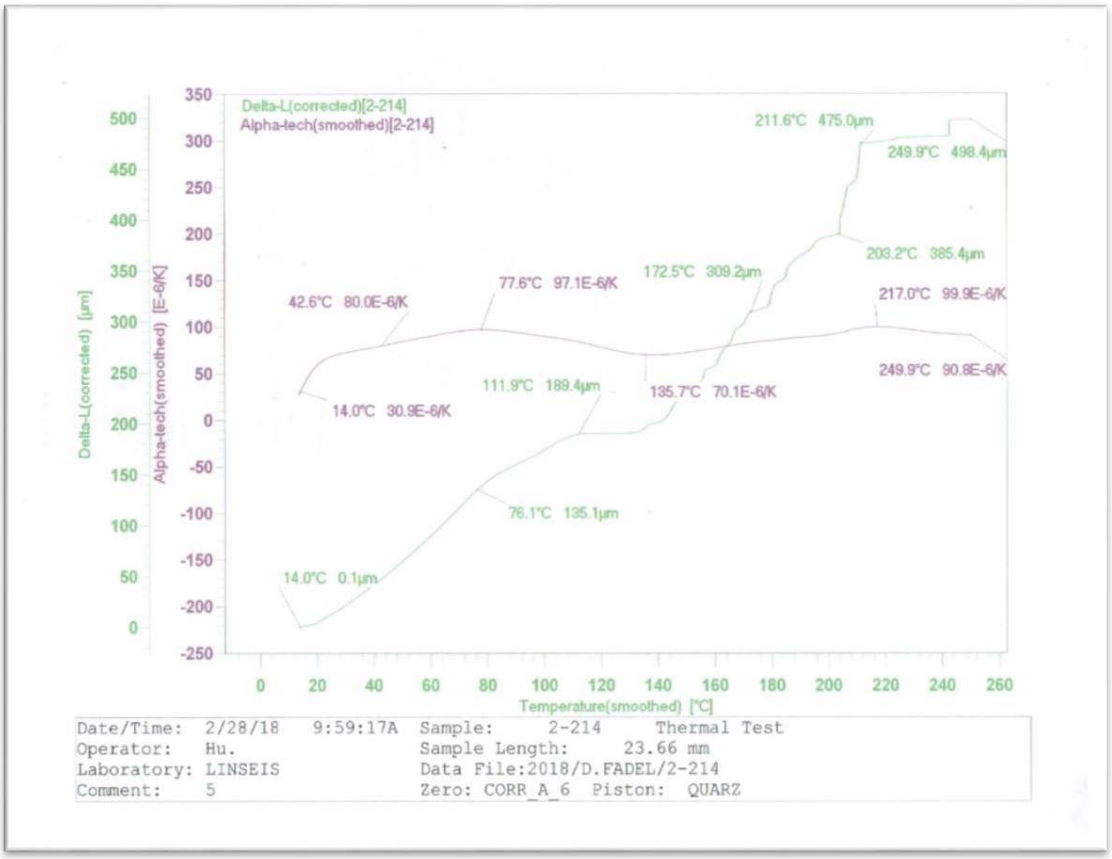


Figure: 11. TMA for 4%wt.$CaAl_2O_4$.

4. Conclusions

All prepared composites (supported by powder nanoparticles) exhibit high resistance to breakage and deformation and this is confirmed by the results of the values of hardness ,impact strength, elastic modulus ,yield strength and fracture toughness .We notice grate decrease in the linear thermal expansion of composite with 3%wt. compared to the other samples where α=0.28x10-6K-1 at temperature 200C ,conversely α= 49.62x10-6K-1 at temperature 200C for pmma .So we suggest using the Nano composite (PMMA\CaAl2O4) at 3%wt suitable material for dental and bone under these conditions and thus constitute a novel new class of applications of prosthetics.

5. References

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