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Nanocharacterization of Dental Materials by Atomic Force Microscopy and their Thermal Degradation Evaluation

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Abstract:

The restorative dental materials must be produced with special characteristics because these are operating in an environment medium with different humidity and temperature. These day-to-day factors play an important role in the lifetime of such dental restorative materials. Resin composites have been by far the most successful in dental applications by meeting several stringent design requirements difficult to achieve with homogeneous materials such as ceramics and metal alloys. Mechanical and tribological properties of direct restorative filling materials are crucial not only to serve and allow similarity with human enamel and dentine but also to compare composites between them and determine objective criteria for their selection. The objective of this research work is to investigate the mechanical and tribological properties of commercial restorative materials using the atomic force microscopy (AFM) technique as a function of the operating temperature. The scope is to estimate the lifetime of such materials starting from their nano-behaviors as nano-wear and nano-indentation tests. This presentation includes the analysis of thermal effect on the composite resin dental material – CHARISMA 40".

Keywords: dental materials; temperature effect; hardness; modulus of elasticity, wear

1. Introduction

Human teeth are tough they are resistant structures that appear on the jaws and around the mouth of vertebrates. The teeth are used, in principals, for masticating food, and for other proposed specialized purposes. Generally, a tooth is composed from one crown and one or more roots. The crown is the functional part of the tooth that is seen above the gum. The root is the tooth part cannot see that support and fix the tooth in the jawbone..

The shape of the crown and the root varies between different teeth in the human mouth. All teeth have the same general structure and consist of three layers [1, 2] as shown in Fig. 1. The hardest tissue in the body is an outer layer of enamel, which is completely inorganic The scope of this study is orientated to the evaluation of the temperature effect on the material properties and wear behavior of composite resin dental material – CHARISMA 40" and its comparison with the tooth enamel.

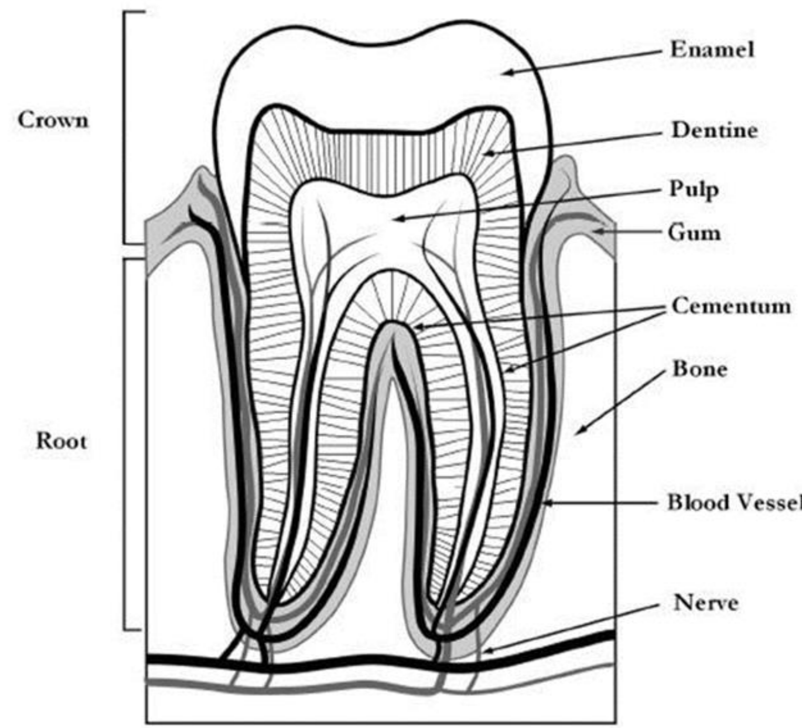


Fig. 1 Human tooth section [1, 2]

2. Topographical analysis

Scope: Analyses of the surface morphology and roughness of investigated samples

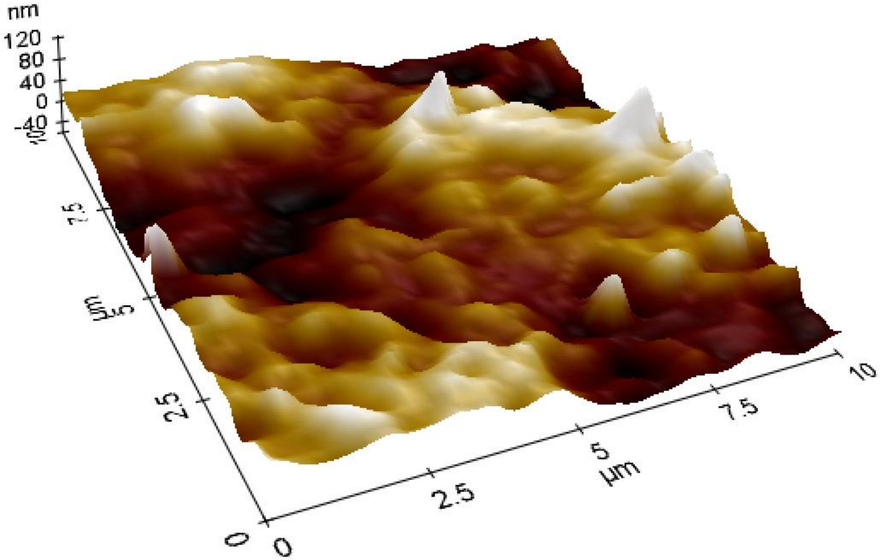
Using method: The non-contact scanning mode of AFM was applied. The type of AFM probe used in this experiment was PPP-NCHR with a force constant of 42N/m and 330kHz the RF. In this operating tapping mode, the AFM tip is vibrating close to the surface measuring the topography by use the attractive atomic force between the tip and sample surface

Input parameters: Scanning area was of 10μm×10μm

Operating conditions: Controlled humidity of 40%RH and temperature of 20°C; antivibration stage to avoid the external noises

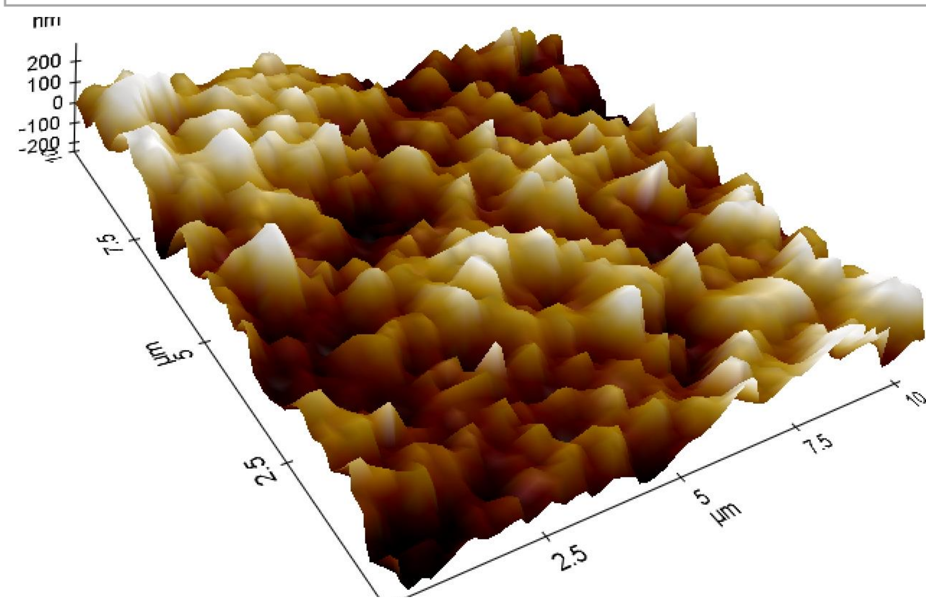
Output results: 3D images, roughness parameters and the grains distribution

Fig. 2 Images (3D) and roughness parameters of samples: (**a**) tooth enamel; (**b**) resin dental material – CHARISMA 40”



(a)

Region	Min(nm)	Max(nm)	Mid(nm)	Mean(nm)	Rpv(nm)	Rq(nm)	Ra(nm)	Rz(nm)	Rsk	Rku
Red	-60.931	123.719	31.394	0.000	184.650	25.438	20.639	165.664	0.355	3.301



(b)

Region	Min(nm)	Max(nm)	Mid(nm)	Mean(nm)	Rpv(nm)	Rq(nm)	Ra(nm)	Rz(nm)	Rsk	Rku
Red	-246.272	282.151	17.939	0.000	528.423	79.689	63.918	456.286	0.035	2.799

3. Hardness and modulus of elasticity

Scope: To determine the modulus of elasticity and the hardness

Using method: The nanoindentation method was applied by using the nanoindentation module of AFM and a Berkovich tip. The results were interpreted based on the Oliver and Pharr Model . The AFM probe used is TD23838 with 272N/m the constant force

Input parameters: The force set-up was selected to 5μm and the indentations were performed in different locations on the material under 30μN the indentation force. The Poisson ration used in the results interpretation was 0.286 for teeth enamel and 0.32 for Charisma 40" [3, 4].

Operating conditions: Controlled humidity of 40%RH and temperature of 20°C; antivibration stage to avoid the external noises

Output results: Nanoindentation curves, hardness and modulus of elasticity

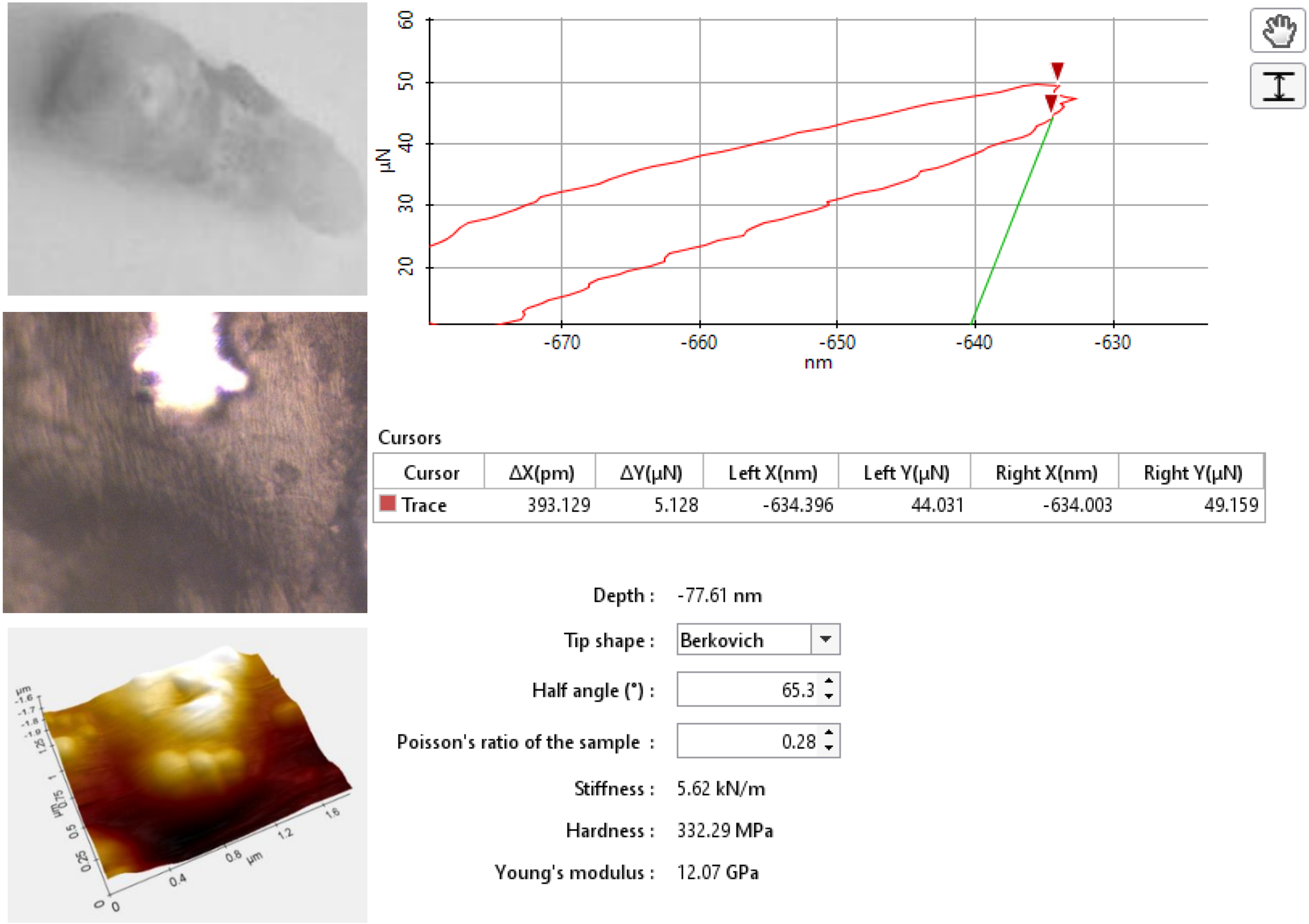


Fig.3 Nanoindentation of teeth enamel

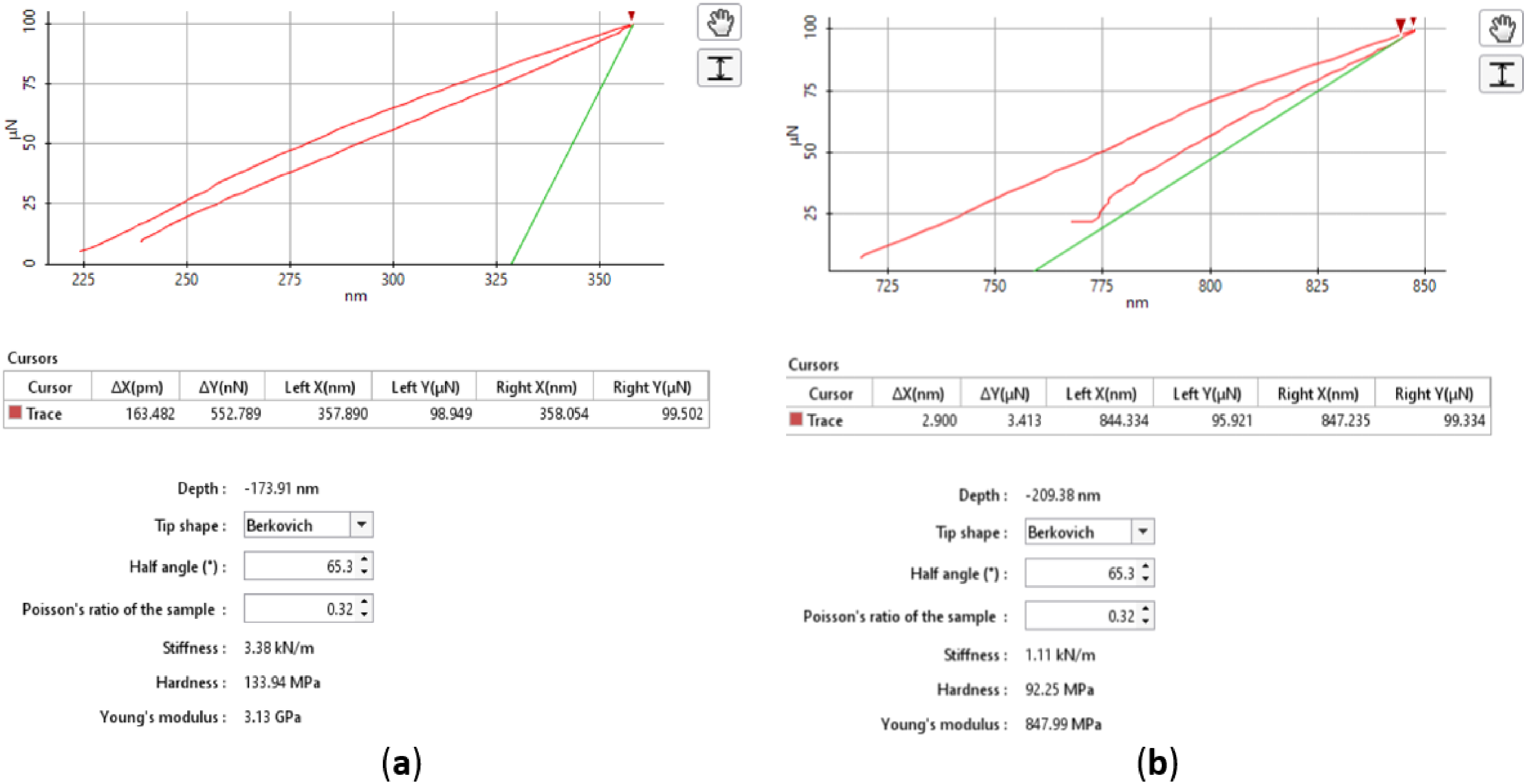


Fig.4 Nanoindentation curves of dental material – CHARISMA 40″ under a force of 100 µN at: (a) 20°C, (b) 100 °C

4. Wear tests

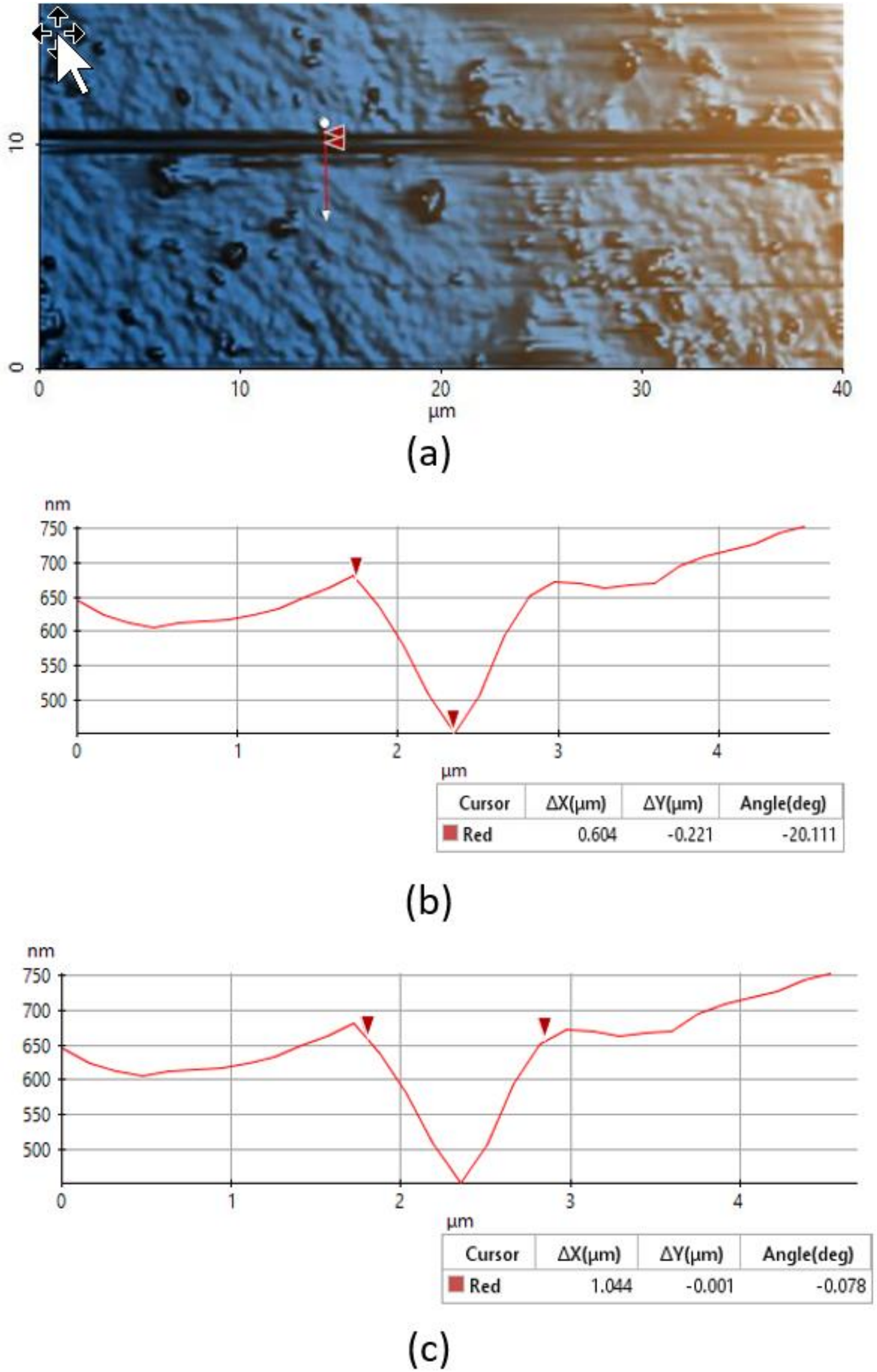
Scope: To determine the wear resistance of investigated dental material and its comparison with teeth material

Using method: The scratching of material by using the contact mode of AFM and a diamond Berkovich tip. After, the scanning of the scratched area by AFM was done by the interpretation of the removed material volume. XEI software as used to measure the dimensions of the triangular section of the removed area. After by considering the length of scratch, the volume of the removed material was estimated

Input parameters: Normal load = 100μN; Scanning rate 1Hz, Scratching time = 5 minutes; Length of scratching 40μm

Operating conditions: Humidity of 40%RH; temperature of 20°C

Output results: Variation of the materials wear as a function of loading time



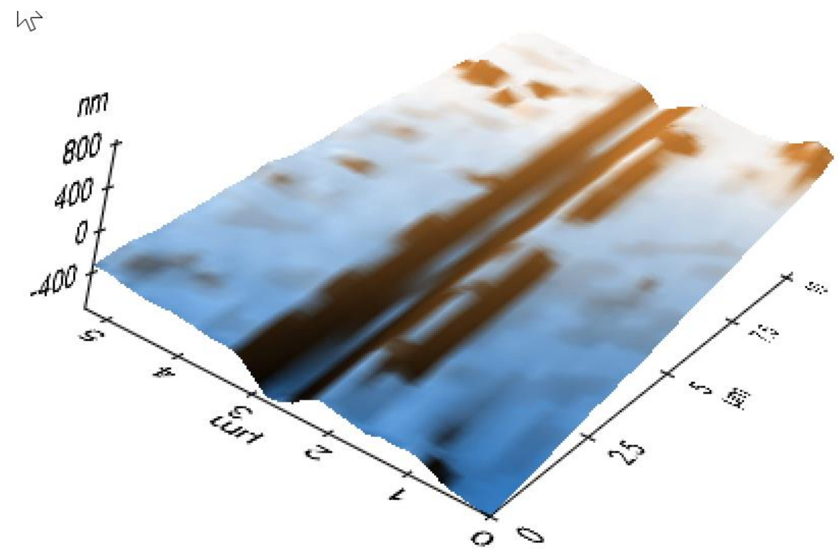
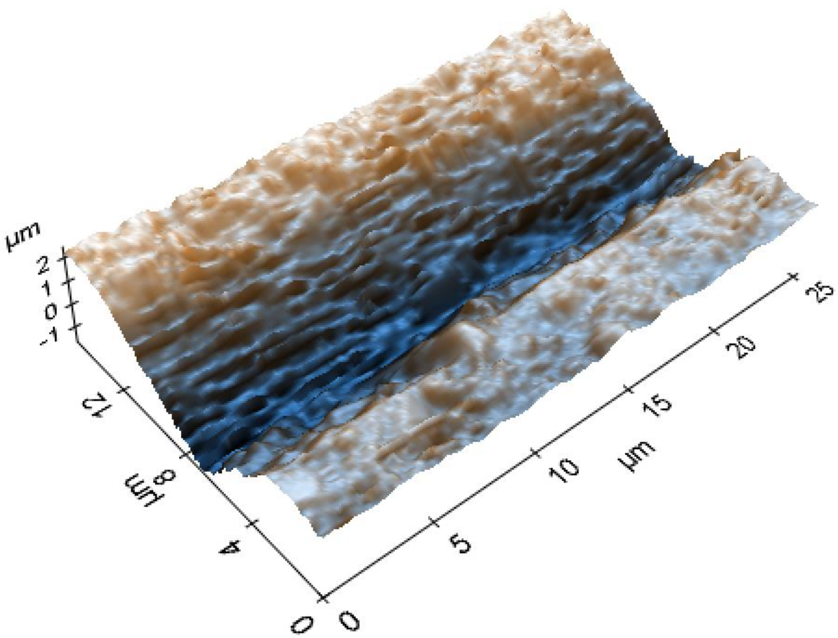


Fig.5 Wear scratch on human teeth under a force of 100μN:

(a) AFM image of the wear area;

(b) the deep of the scratch;

(c) the width of the scratched zone



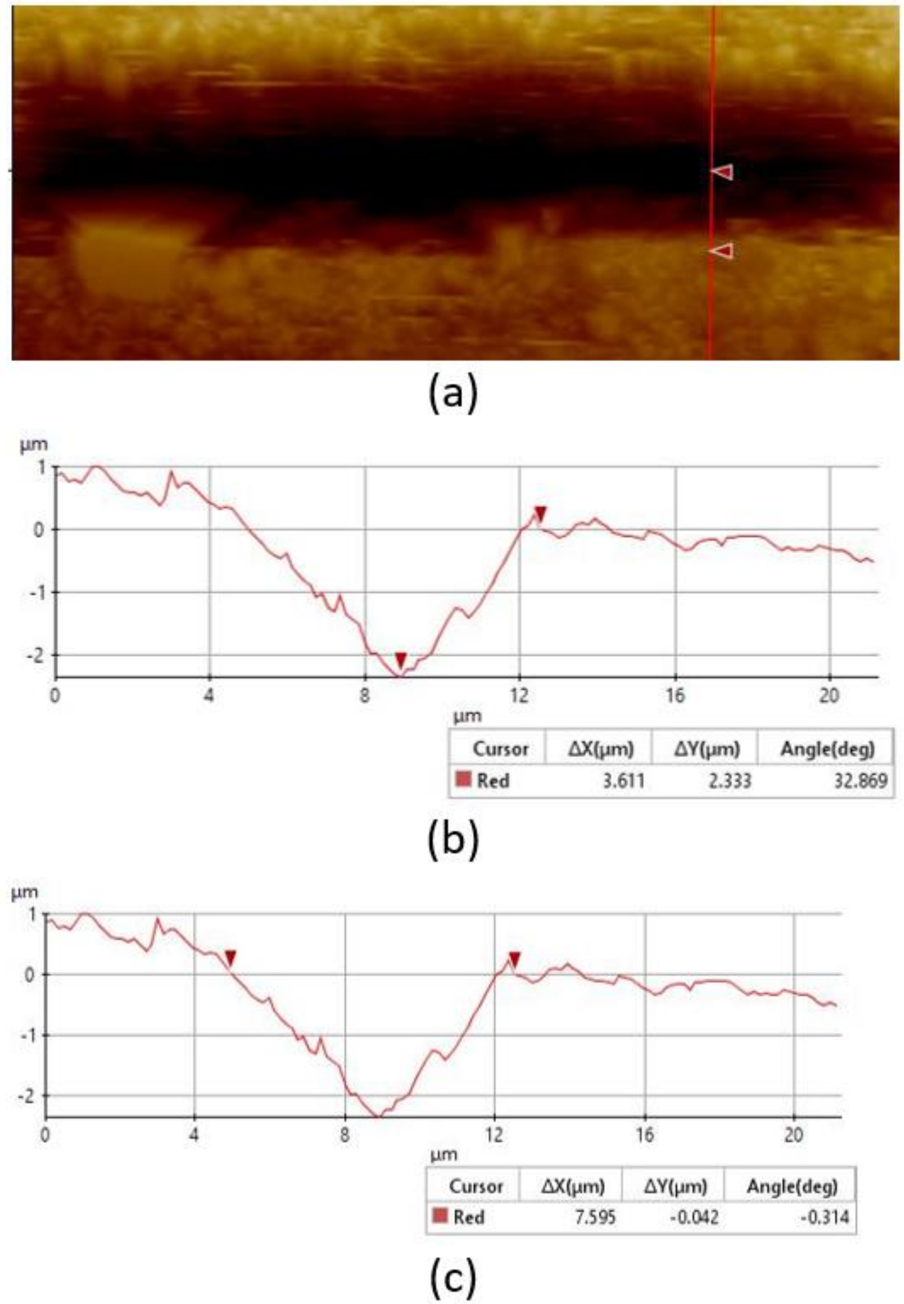
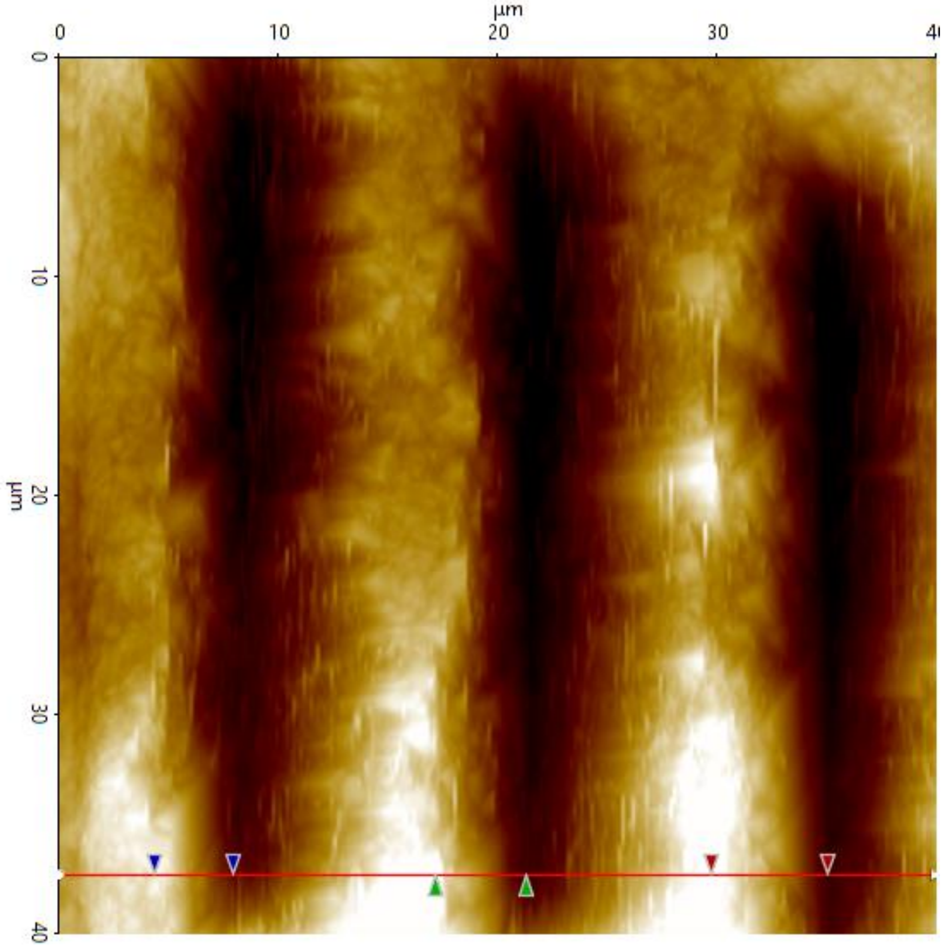


Fig.6 Wear scratch on dental material – CHARISMA 40" under a force of 100µN:
(a) AFM image of the wear area;
(b) the deep of the scratch;
(c) the width of the scratched zone



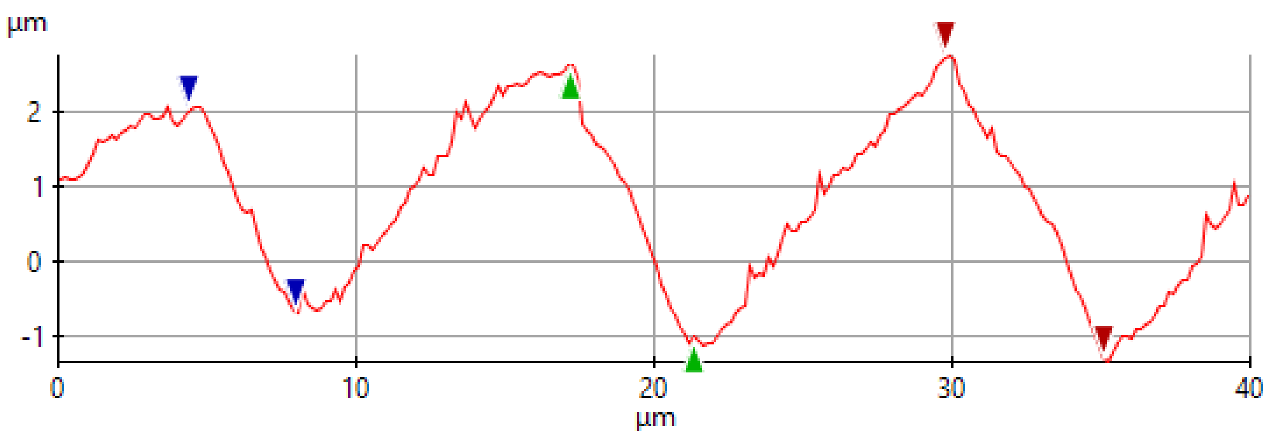
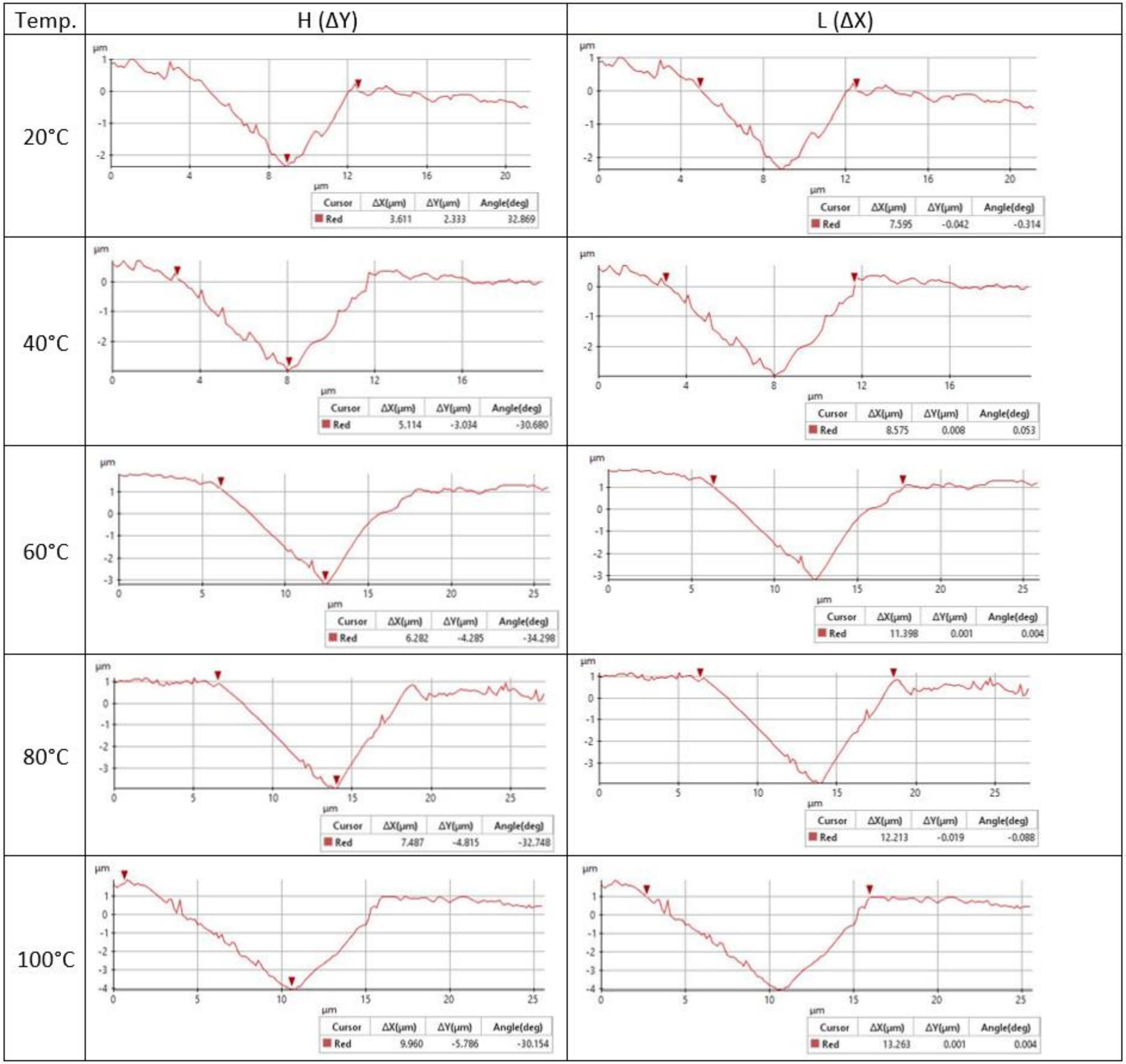


Fig.7 Wear scratch variation of dental material – CHARISMA 40" under a force of 100µN for different temperatures



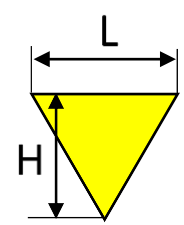


Fig.8 Wear area dimensions (high and length) of dental material – CHARISMA 40" for different temperatures under a scratching forces F=100µN

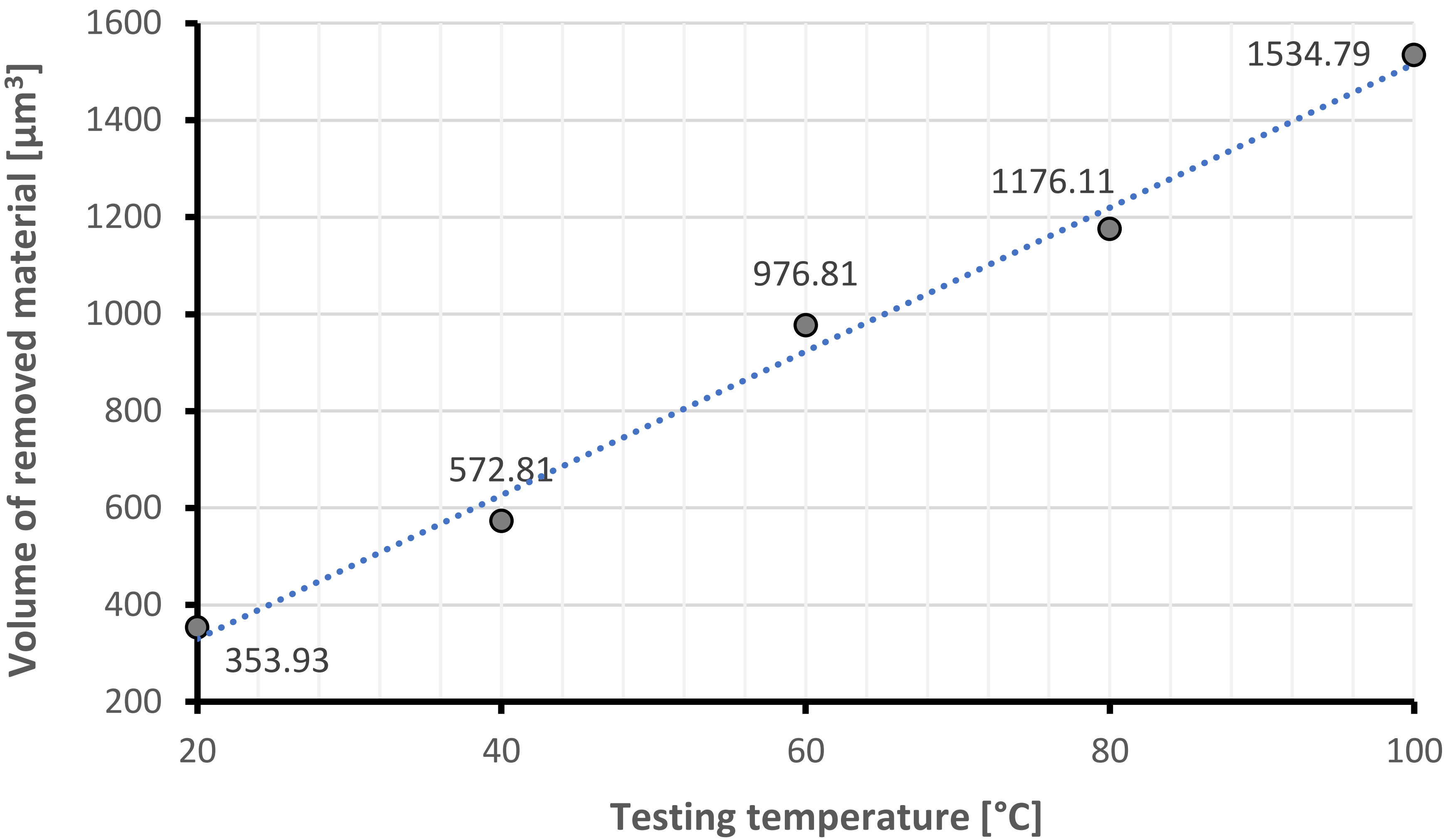


Fig.9 Wear volume variation of dental material – CHARISMA 40” for different temperatures under a scratching forces F=100µN

5. Conclusions

One of the attractive methods for measuring the nano-tribomechanical behavior of small specimen volumes in dental materials is nanoindentation and scratching. Using this technique, the tribomechanical properties of nano composite resins were investigated. Experimental study has been carried out for CHARISMA 40" at different temperatures representing several steps of severity conditions for material in test. This study has allowed concluding that, the hardness of dental materials decreases as temperature increases. Experimentally study was performed using a normal loads and time-duration tests i.e., representing several steps of severity conditions for materials under investigation. As a function of temperature, the hardness and modulus of elasticity is modified which give the high ration of wear removed material and increase the possibility of thermal degradation.

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