ISSN : 0974 - 7532 Volume 8 Issue 2

Research & Reviews in

BioSciences

Regular Paper

RRBS, 8(2), 2014 [66-72]

An in-vitro study of the effect of magnetic resonance imaging on physico-mechanical and structure of dental ceramic restorations

Abu Bakr El-Bediwi[1]*, Thoraya El-Helaly[1], Amal Sakrana[2], Mustafa Kamal[1]

[1]Metal Physics Lab., Physics Department, Faculty of Science, Mansoura University, (EGYPT)

[2]Conservative Dentistry Department, Faculty of Dentistry, Mansoura University, (EGYPT)

ABSTRACT

Magnetic Resonance Imaging (MRI) scan is a painless radiology technique without no known side effects and its precise accuracy in detecting structural abnormalities of the body. MRI is also best suited for cases when a patient is to undergo the exam several times successively in the short term, because, unlike CT, it does not expose the patient to the hazards of ionizing radiation. In the present study the effect of MRI on microstructure, hardness and minimum shear stress of Porcelain and Zirconia Dental Ceramic have been studied and analyzed. Vickers hardness and minimum shear strength values of Zirconia and porcelain decreased but crack velocity and crack length increased after exposure to MRI. The interaction of non-ionizing radio frequency (RF) signals of MRI with Ceramic materials caused a structure change which effects on physico mechanical properties.

KEYWORDS

Porcelain;
Zirconia;
MRI;
Structure;
Hardness;
Crack;
Minimum shear stress.

INTRODUCTION

Zirconia (zirconium oxide) based ceramics have become a very popular type of all-ceramic restorations. Zirconia-based restorations can be a near ideal choice for restoring crowns, fixed partial dentures, and implants in esthetic areas. The first study of implants on zirconia was recorded in 1993, when a group of researchers inserted experimental Y-TPZ implants in the mandible of dogs[1,2]. Different oxides, such as yttrium oxide (Y_2O_3), calcium oxide (CaO) or magnesium oxide (MgO), can be added to zirconia to stabilize it, allowing the tetragonal form to exist at room temperature after sintering. The addition of varying amounts of stabilizers allows the formation of partially or fully stabilized zirconia which, when combined with changes in processes, may result in ceramics with exceptional properties such as high flexural strength and fracture toughness, high hardness, excellent chemical resistance and good conductivity ions. The addition of stabilizing oxides is important because it allows the maintenance of the tetragonal form at room temperature[3]. Zirconia is used to make ceramic knives. Because of its hardness, Zirconia based cutlery stays sharp longer than a stainless steel equivalent[4]. Dental ceramics are able to mimic natural teeth due to their excellent physical properties such as esthetics, biocompatibility, low thermal conductibility and wear resistance[5-7]. Because of these features, dental ceramics have been extensively used in several rehabilitation procedures, including inlays, onlays, crowns, and porcelain veneers[8]. The purpose of this study was to evaluate whether the effect of MRI on microstructure, hardness and minimum shear stress of Porcelain and Zirconia Dental Ceramic materials.

MATERIALS AND METHODS

The specimens used in the present work are dental porcelain (Vita VMK, Master, VITA Zahnfabrik, Germany) were prepared in a standardized manner and according to the manufacturer's directions in rectangular stainless steel split mold (40 mm- 5 mm – 3 mm) and Zirconium blank for dental restorations, class II ceramic from white peaks Dental Systems GmbH & Co. KG, langeheide 9 D-45239 Essen. The specimens were prepared in convenient shape for all tests such as microstructure and Vickers microhardness. Microstructure of used specimens was performed on the flat surface of all specimens using an Shimadzu X–ray Diffractometer (Dx–30, Japan) of Cu–Kα radiation with λ=1.54056 Å at 45 kV and 35 mA and Ni–filter in the angular range 2θ ranging from 0 to 90° in continuous mode with a scan speed 5 deg/min. Microhardness test of used specimens were conducted using a digital Vickers microhardness tester, (Model FM–7, Tokyo, Japan), applying a different loads for different indentation time via a Vickers diamond pyramid.

RESULTS AND DISCUSSIONS

X-ray analysis

The interaction effects between the non-ionizing radio frequency (RF) signals of MRI and such dental ceramics materials might be of clinical significant if the properties of these dental materials are adversely affected. The effect of non-ionizing radio frequency (RF) signals of MRI on microstructure was studied by x-ray diffractometer. Figure 1 shows x-ray diffraction patterns of Zirconia ceramics dental material before and after exposure to MRI for different time, (0, 15 and 30 minutes). The analysis of x-ray diffraction patterns (intensity, position and orientation) shows change in these formed peaks features, ZiO_2, such as crystallinty and crystal size as shown in TABLE 1.

Figure 2 shows x-ray diffraction patterns of Porcelain ceramics dental material before and after exposure by MRI at different time, (0, 15 and 30 minutes). The analysis of x-ray diffraction patterns (intensity, position and orientation) shows a variation in the main matrix peak feature (amorphous part) and other formed phases (accumulated particles or cluster) as seen in Figure 2. The change in matrix microstructure of Zirconia and Porcelain ceramic dental materials after exposure to MRI. That is because MRI has thermal and magnetic effects due moving and migration in matrix component changed its microstructure (crystallinty and crystal size) and that is agree with pervious results[9-12].

TABLE 1 : X-ray diffraction analysis of Zirconia before and after exposure to MRI

2θ	d-spacing	Intensity %	FWHM
Untreated Zirconia sample			
28.1900	3.16567	1.04	0.0900
30.1676	2.96251	100	0.3936
34.6515	2.58874	14.27	0.3346
35.2047	2.54932	9.47	0.3149
43.1017	2.09878	1.14	0.3346
50.1959	1.81753	41.91	0.3542
59.3765	1.55657	18.72	0.3739
60.0984	1.53958	18.86	0.2952
62.7105	1.48159	5.83	0.2558
68.6500	1.36718	0.28	0.0900
73.0326	1.29558	2.49	0.4723
74.4026	1.27403	3.23	0.4800
After exposure for 15 minutes			
30.1860	2.96074	100	0.3936
34.6553	2.58846	13.10	0.3149
35.2311	2.54747	7.53	0.2755
43.0556	2.10092	1.03	0.5510
50.1627	1.81866	34.46	0.3739
59.4011	1.55598	15.55	0.3739
60.0920	1.53973	15.68	0.3542
62.8471	1.47870	4.61	0.3739
73.0558	1.29523	2.44	0.4723
74.5252	1.27224	2.68	0.4320
After exposure for 30 minutes			
30.1949	2.95988	100	0.2362
34.7060	2.58480	13.87	0.2362
35.2849	2.54371	6.87	0.2755
50.1518	1.81903	36.26	0.2362
59.3171	1.55798	15.39	0.3936
60.0880	1.53983	16.54	0.3936
62.7903	1.47990	4.45	0.4723
73.1577	1.29367	2.04	0.4723
74.4200	1.27377	3.18	0.4800

Regular Paper

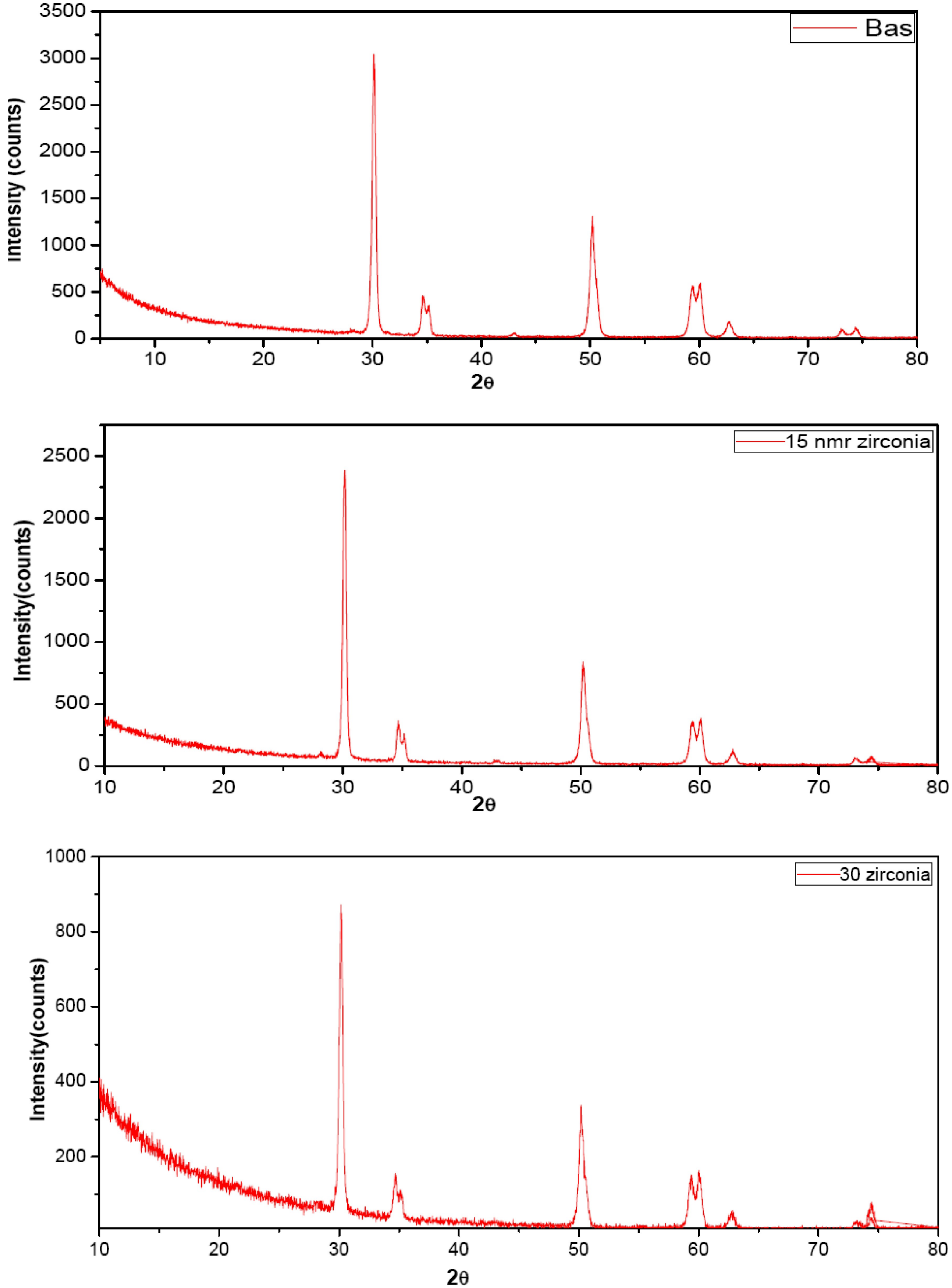


Figure 1 : X-ray diffraction patterns of Zirconia before and after exposure to MRI

Vickers hardness and minimum shear stress

Hardness is a property with a low coefficient of variation when compared with other mechanical properties tested. In general hardness is defined as "Resistance of material to plastic deformation", usually by indentation. However, the term hardness may also refer to stiffness or temper or resistance to scratching abrasion, or cutting.

The microhardness value was conducted using a

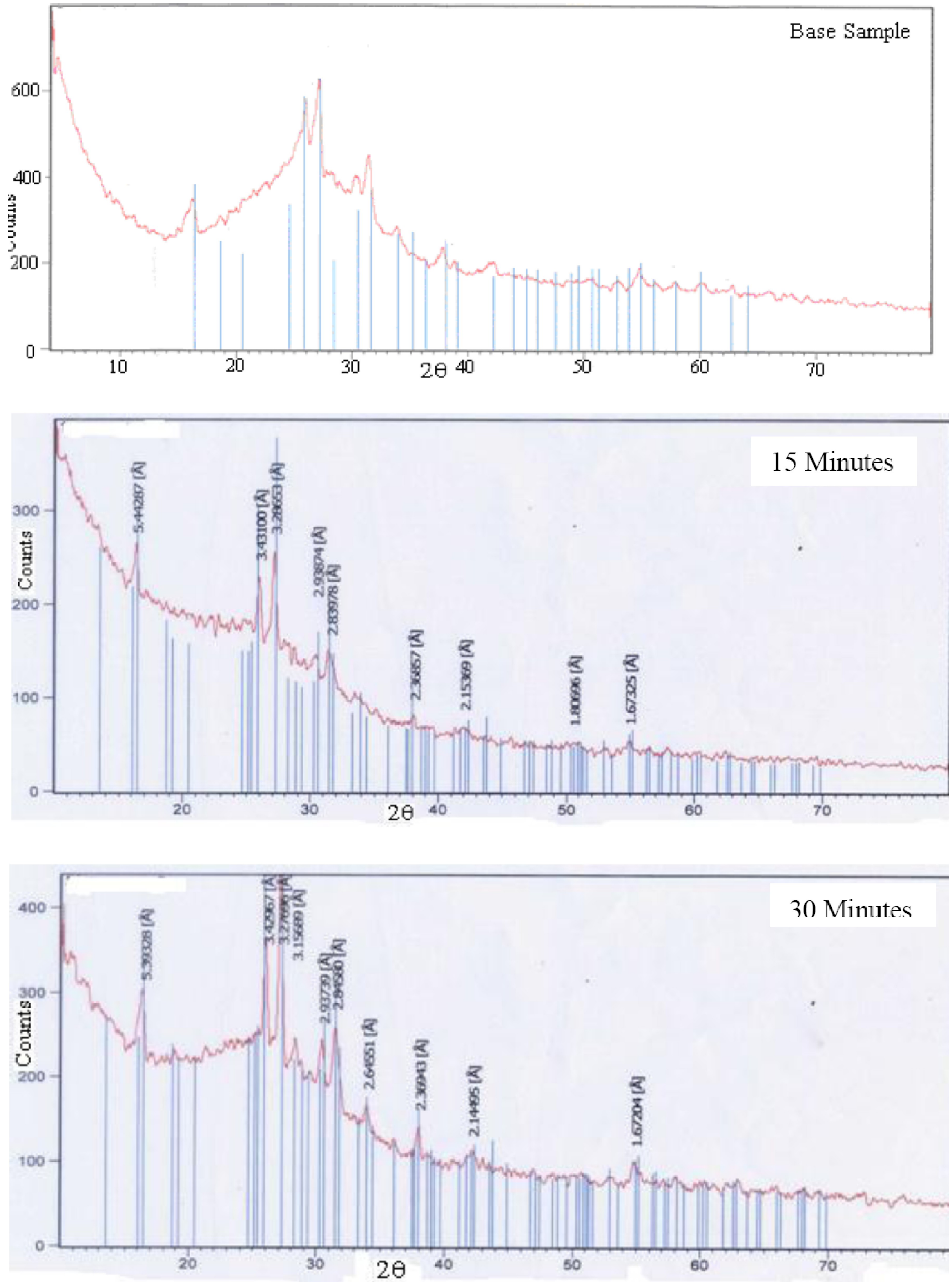
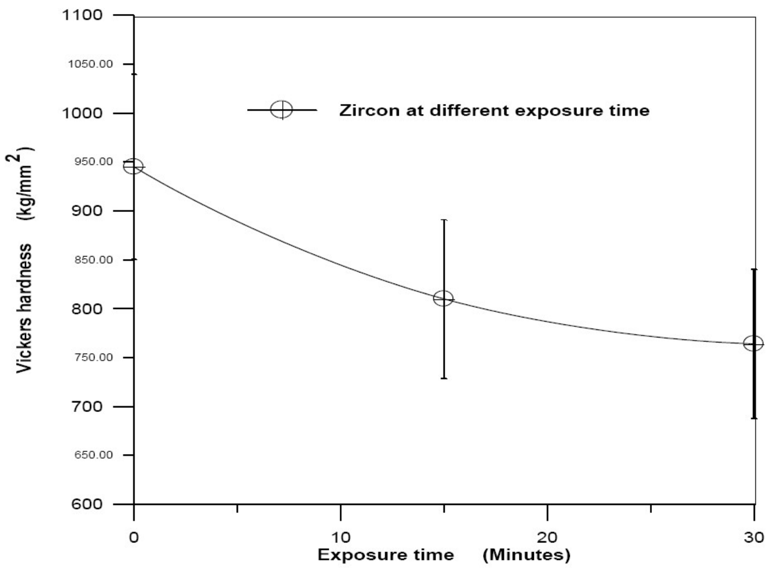


Figure 2 : X-ray diffraction patterns of dental porcelain before and after exposure to MRI

digital Vickers microhardness tester, applying a load of 100 g for 5 s, for ceramic dental materials. Vickers hardness value of Zirconia and porcelain ceramic materials before and after exposure to MRI for different time, (0, 15 and 30 minutes) are shown in Figures 3 and 4. Vickers hardness value of Zirconia and porcelain ceramic materials decreased after exposure to MRI and that is agree with other pervious results[13,14]. That is because the MRI changed matrix microstructure with increasing crystal size and decreased crystallinty as



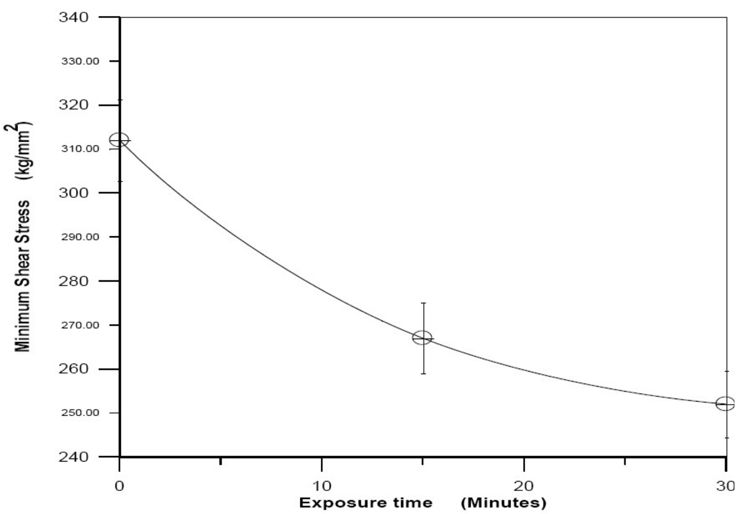


Figure 3 : Vickers hardness and minimum shear stress of Zirconia before and after exposure to MRI

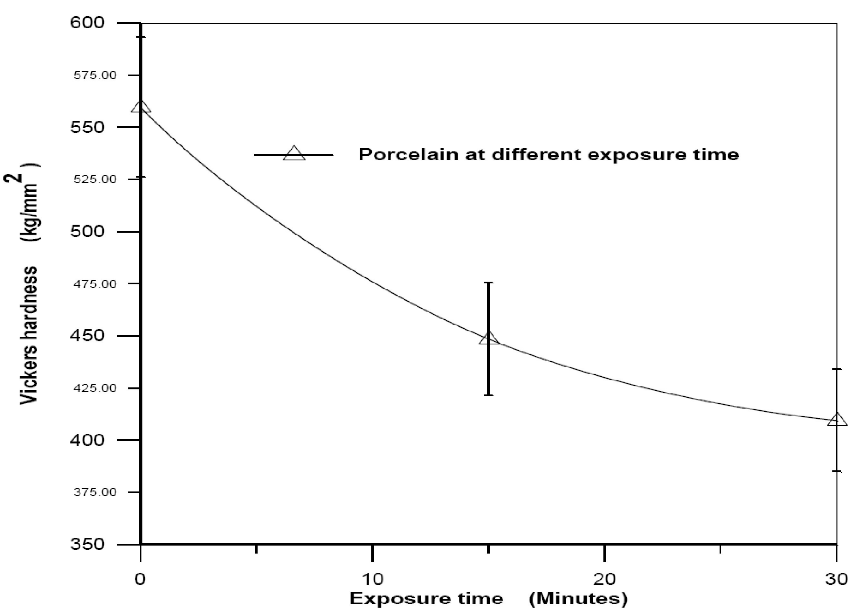


Figure 4 : Vickers hardness of dental porcelain before and after exposure to MRI

shown in x-ray analysis.

The minimum shear stress (τ_m) value of Zirconia and porcelain ceramic materials before and after annealing at 600, 700 and 800 °C for two hours was calculated[15] and then shown in Figure 3.

The Vickers test is reliable for measuring the hardness of metals, and also used on ceramic materials. The indenter employed in the Vickers test is a square-based pyramid whose opposite sides meet at the apex at an angle of 136º. The diamond is pressed into the surface of the material at loads ranging up to approximately 120 kilograms-force, and the size of the impression (usually no more than 0.5 mm) is measured with the aid of a calibrated microscope. Diameter diamond length and the velocity of lines due to applied load on Zirconia ceramic material surface before and after exposure to MRI for different time, (0, 15 and 30 minutes) are shown in Figures 5. Diamond length and the velocity of lines values increased after exposure to MRI.

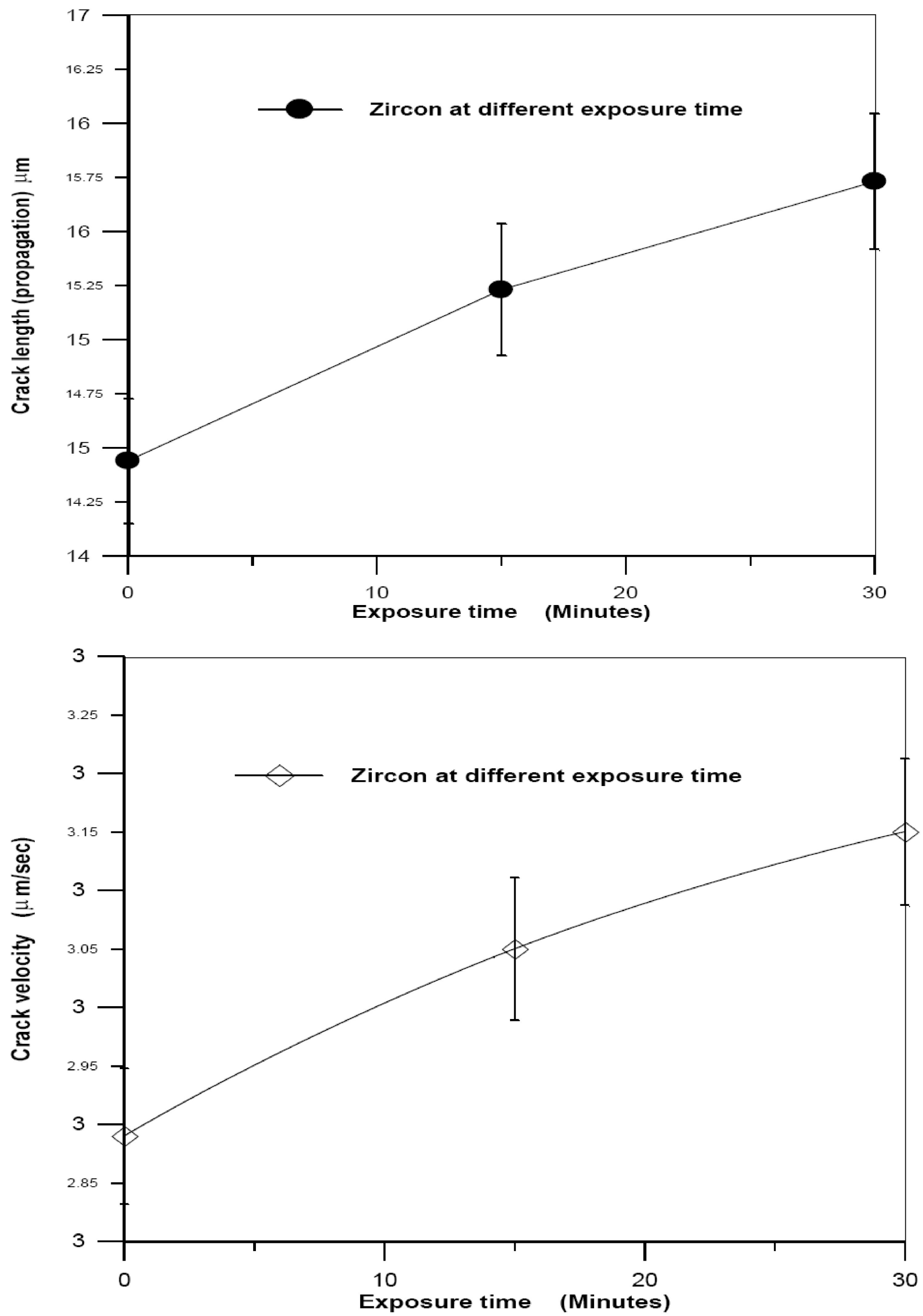


Figure 5 : Crack length and crack velocity of Zirconia before and after exposure to MRI

Regular Paper

CONCLUSION

Microstructure of Porcelain and Zirconia Dental Ceramic materials changed after exposure to MRI. Vickers hardness and minimum shear strength values of Zirconia and porcelain decreased but crack velocity and crack length increased after exposure to MRI. That is because the interaction of non-ionizing radio frequency (RF) signals of MRI with Ceramic materials caused a structure change which effects on physico-mechanical properties.

RECOMMENDATION

If The patient need scan by nuclear magnetic resonance imaging (MRI), the scan time should be small.

REFERENCES

[1] A.N.Cranin, P.A.Schnitman, S.M.Rabkin, E.J.Onesto; Alumina and zirconia coated vitallium oral endosteal implants in beagles, J.Biomed.Mater.Res., **9**, 257-262 **(1975)**.

[2] C.Miani, C.Piconi, D.Piselli, M.Ponti; Prove sperimentali in vivo della zirconia in Implantologia Orale, Rev.Ital.Osseoint., **3**, 23-34 **(1993)**.

[3] R.H.J.Hannink, P.M.Kelly, B.C.Muddle; Transformation toughening in zirconia – containing ceramics, J.Am.Ceram.Soc., **83**, 461-487 **(2000)**.

[4] Papaspyridakos, Panos Kunal Lal; Complete arch implant rehabilitation using subtractive rapid prototyping and porcelain fused to zirconia prosthesis: A clinical report, The Journal of Prosthetic Dentistry, **100(3)**, 165–172 **(2008)**.

[5] Dental porcelain; In: W.J.O'Brien, (Ed); Dental materials and their Selection, 3rd Edition, Chicago: Quintessence, 210 **(2002)**.

[6] A.O.E.El-Karaksi, G.I.Shehab, M.E.Eskander; Effect of reglazing and of polishing on the surface roughness of new ceramic restoration, Hi Ceram, Egypt Dent.J., **39**, 485-90 **(1993)**.

[7] G.B.Camacho, D.Vinha, H.Panzeri, T.Nonaka, M.Gonçalves; Surface roughness of a dental ceramic after polishing with different vehicles and diamond pastes, Braz Dent.J., **17**, 191-4 **(2006)**.

[8] KJ.Anusavice; Recent developments in restorative dental ceramics, J.Am.Dent.Assoc., **124**, 72-84 **(1993)**.

[9] A.B.El-Bediwi, A.A.El-Fallal, O.H.Abo-El-Naga; Influence of therapeutic dose gamma radiation and MRI on structure and mechanical properties of Resin-composites dental materials, Materials Science: An Indian Journal, **6(2)**, **(2010)**.

[10] A.B.El-Bediwi, M.Saad, A.A.El-Fallal, S.El-Khaligy; Influence of gamma radiation and magnetic resonance imaging radiation on microstructure, hardness and electrochemical corrosion behavior of Co-Cr based dental alloy, Radiation Effect & Defects in Solids, **166(3)**, 223–227 **(2011)**.

[11] A.B.El-Bediwi, M.Saad, A.A.El-Fallal, T.El–Helaly; Effect of MRI on structure, roughness, hardness and electrochemical corrosion behavior of biomaterial Protechno® - N dental alloy, Materials Science: An Indian Journal, **8(2)**, **(2012)**.

[12] A.B.El-Bediwi, M.Saad, A.A.El-Fallal; Modification of titanium surface by magnetic resonance signals and gamma radiation, MSAIJ, **9(10)**, 402-410 **(2013)**.

[13] K.A.Schulzea, S.J.Marshalla, S.A.Ganskyb, G.W.Marshalla; Dent Mater., **19(7)**, 612 **(2003)**.

[14] D.dc Adriana, A.C.S.Mario, M.A.Glaucia, N.de S.R.Alessandra, S.B.Vanderlei, N.B.Frab; Mat.Res., 3 **(2008)**.

[15] S.Timoshenko, J.Goodier; Theory of Elasticity, 3rd Edition, McGraw- Hill: NewYork, 407 **(1970)**.