IBN AL- HAITHAM J. FOR PURE & APPL. SCI. VOL.23 (2) 2010

The Corrosion Behavior of Different Gauges of Stainless Steel Wire Use in Removable Partial Denture and Orthodontics Appliances

N. S. Mansoor
Foundation of Technical Education, College of Health and Medical Technology

Abstract

Wires are commonly used for the construction of orthodontic appliances and occasionally as wrought clasps and rests on partial dentures.

The corrosion resistance is the most important properties of dental alloy. Corrosion process reported to cause a numerous adverse effects on both living tissue and restoration .The conditions in the mouth are very suitable for the occurrence of corrosion. The main objective of this study was to evaluate the corrosion behavior of different gauges of stainless steel wire in artificial saliva .Four gauges of dental stainless steel wire used in orthodontic and removable partial denture were used in this study 0.6mm.,0.7mm.,0 .8mm.&1.0mm.).The specimens were divided according to gauge in to four groups(A,B,C,&D) ,ten specimens in each group .Each wire was cut by using wire cutter to get wire with (1cm) in length .Artificial saliva of Fusayama Meyer type was used as the testing solution .Sensitive electronic balance was used to weight the sample before immersion in solution and recording the results.This this represents the first weight(W_1).Each specimen was put inside a test tube , and held using dental floss in a way that the specimen was fully immersed in the solution from all sides . The specimens then were put inside an incubator ,which was adjusted at 37±2 and left for 14 days .At the end of immersion period ; the specimens were removed from the solution and then allowed to dry and were balanced then the results were recorded .This represents the second weight (W_2) .After obtaining the (W_1)&(W_2) the corrosion rate was calculated .

The results before and after immersion showed that the 0.6 mm.& 0.7mm stainless steel wire gave the highest and more corrosion resistance value than 0.8mm&1.0mm.stainless steel wire .

The result showed there is a statistical significance between (W_1&W_2) of 0.8mm stainless steel wire and highly significant between (W_1&W_2) of 1.0mm. stainless steel wire .

The comparison of the results after calculating results in corrosion rate formula showed that the 1.0mm stainless steel wire more corrosion resistance followed by 0.8mm wire ,from 0.6mm& 0.7 mm wire .

Introduction

Wires are used by the orthodontist and are some times used for clasps in connection with partial dentures.

Until the 1930 the only orthodontic wires available were made of gold and austenitic stainless steel with greater strength. [1]

Various wire sizes and four arch wire alloys are now available stainless steel, cobalt, chromium, nickel titanium and beta titanium. The ideal orthodontic wire properties can be described in layer terms of the following criteria ,but in contemporary practice ,no one wire meets all these requirements , and the best result is obtained by using specific wire for specific purpose ,the criteria are : strong ,resilience , weld able , solder able ,low cost , low friction ,and bio compatibility .[2]

There are essentially three types of stainless steels. This classification is with approximate compositions. The type includes: ferrite stainless steel, martenstic stainless steel &austenitic stainless steel. [1]

Bio compatibility and corrosion resistance of alloys were related to the composition and elements or irons related in to surrounding medium. [3]

The corrosion resistance is of great importance because of possible biological reaction (adverse effects on both living tissues) and because of possible destruction of the restoration [4, 5] and lead to roughening of the surface, weakening of the appliances, and liberation of elements from the metal or alloy [6].Release of elements can produce discoloration of adjacent soft tissues and allergic reactions in susceptible patients [7].Corrosion can severely limit the fatigue life and ultimate strength of the material leading to mechanical failure of the dental materials .[8]

Corrosion products were implicated in causing local pain or swelling in the region of the orthodontic appliances in the absence of infection, which can lead to secondary infection. [9]

This study aims to investigate the corrosion behavior of stainless steel wire with different gauge in artificial saliva.

Materials and Methods

Materials, Instruments & Equipments:

* Distilled water (Iraq)
* NaCl, KCl, $CaCl_2$, $2H_2O$, NaH_2PO_4& urea crystal (artificial saliva of Fusayama, Meyer type)
*Dental stainless steel wire with different gauge 0.6 mm, 0.7 mm, 0.8 mm & 1.0 mm . (china). **fig (1)**
*Acetone material
* Cotton
* Dental floss
* Sodium bicarbonate & nitric acid.

Instrument & Equipments:-

- Sensitive electronic balance (Germany)
- Incubator (England)
- Millimeter ruler
- Wire cutter
- Electronic pH meter (Japan)
- Tubes (testing tube & measuring tube)
- Olympus photomicroscope system with exposure control unites (Japan).

Methods

Four gauges of dental stainless steel wire used in orthodontic & removable partial denture were used in this study, (0.6 mm, 0.7 mm, 0.8 mm & 1.0 mm).

The specimens were divided according to gauge into four groups, (A, B, C &D) ten specimens in each group.fig (2)

Dental stainless steel wire with different gauge (diameter) were used in this study 0.6 mm , 0.7 mm , 0.8 mm , &1.0 mm) that using in removable orthodontic & removable partial denture fig (1).Each wire was cut by used wire cutter to get wire with 1 cm in length (used ruler to measure the length of wire).fig (3)

The finished were rinsed in distilled water to remove any attached particles, and then allowed to dry in air .The specimen then were immersed in an acetone solution for about (5 minutes) in order to remove any adsorbed particles, and then allowed to dry in air. fig (4)

Sensitive Electronic balance was used to weight the samples before immersion in solution & recording the results .This represented the first weight (w_1).

Preparation of the testing solution

Artificial saliva of Fusayama- Meyer type was used as the testing solution [10] .The composition of artificial saliva mentioned in table (1).

An electronic balance was used to prepare the required amounts of each element of artificial saliva which were mixed in one liter of distilled water.

The pH of the solution is adjusted at (pH=6) by using sodium bicarbonate .This stimulates the pH of natural saliva. The pH of the solution was estimated by using an electronic meter.

So 2ml of nitric acid (normality = 6) was added to each sample solution in order to increase the dissolution of the ions in the solution.Each specimen was put inside a test tube, and held using a dental floss in way that the specimen was fully immersed in the solution from all sides. In each test tube 30 ml of the testing solution and then the test tubes were locked, the artificial saliva was prepared as described in table (1).

The specimen then were put inside incubator which was adjusted at 37 $C^{\circ} \pm 2$ and left for 14 days [11] the solutions were shaked for about (5 seconds) daily in order to prevent the solution from being precipitated. At the end of the immersion period, the specimen were removed from the solution &then allowed to dry & were balanced then the result was recorded .This represented the second weight (w_2).

The corrosion rate calculated by the following formula: [12]

$$\textbf{Corrosion rate} = \Delta W / A.T$$

$\Delta W = W_1 - W_2$

W_1 =Weight before corrosion

W_2 = Weight after corrosion

A = Exposure area

T = Time

Olympus photomicroscope device used to show the type of corrosion occured in wire. Fig (5)

The corrosion rate data obtained were recorded and submitted to statistical analysis.

Statistical Analyses

The suitable statistical methods were used in order to analyze and assess the results, they include the followings:

1- Descriptive statistics:

A) Statistical tables including observed frequencies.

B) Summary statistic of the readings distribution (mean, SD, SR, minimum & maximum).

C) Graphical presentation by (bar - charts).

2 – Inferential statistics:

These were used to accept or reject the statistical hypotheses, they include the followings:

A) (ANOVA) Analysis of variation test (F-test).

B) (LSD) less Significant difference (F-test).

Note: The comparison of significant (P-value) in any test were:

S= Significant difference ($P<0.05$).

HS= Highly Significant difference ($P<0.01$).

NS= Non Significant difference ($P>0.05$).

Results

Corrosion rate test results

Results of corrosion rate calculated in (Δw/mg) were obtained for (40) samples ,which include the four groups (ten samples) in each group.

The mean of samples, standard deviation, slandered error, maximum &minimum for each group (before corrosion and after corrosion) are listed in table (2)& table (3)

Graphical presentation by bar chart between the mean of wire weight (before and after the corrosion) of the four gauges , shown in fig (6). Graphical presentation by bar chart between the mean corrosion rates of the four groups, is shown in fig (7). The charts represent clearly change in response between the corrosion rate according to their statistic values**.**

Inferential statistical methods represented by analysis of variance "ANOVa" test show that there are statistically significant difference at $P<0.05$ (was recorded between at least two different groups).Table (6)

The source of difference is investigated by further complement analysis of data by using LSD (least significant difference) test to examine the difference between the different pairs of the four groups as shown in table (7)

Discussion

Wires often remain in the oral cavity for several months. Whether they are part of fixed or removable orthodontic appliance. The wire should therefore have good corrosion resistance in order to remain with stand attack from oral fluid.

The corrosion resistance of alloy is one of the most important factors in dental prosthesis success, because of possible biological reactions and because of possible destruction of the restoration [4,5].

The oral cavity provides an ideal and unique environment for studying the biological processes involving metallic dental aids. Dental materials within the mouth interact continuously with physiological fluids. Oral tissues are exposed to a veritable bombardment of both chemical and physical stimuli, as well as the metabolism of about 30 species of bacteria (the total salivary bacterial count is said to be five thousand million/ml of saliva). Saliva is a hypotonic solution containing bioactonate, chloride, potassium, sodium, nitrogenous compounds and protein [13]. The pH of saliva varies from 5.2 to 7.8. Corrosion, the graded degradation of materials by electrochemical attack, is of concern particularly when orthodontic appliances are placed in the hostile electrolytic environment provided by the human mouth [14]. Factors such as temperature, quantity and quality of saliva, plaque, pH, proteins, physical/chemical properties of solids/liquids food and oral conditions may influence corrosion processes.[15,16]

Table (2) showed the differences in weight between different wires. This is due to the fact that the different wire had different gauge.

Table (3) showed the differences between different wires. This is due to the fact that the different wire had different gauge and different corrosion behavior of the wire.

Comparison between W_1& W_2 of each gauge of wire mentioned in table (4). This table showed non statistical significant in mean of 0.6mm. stainless steel wire and non statistical significant in mean of 0.7mm.stainless steel wire ,but showed statistical significant in mean of 0.8mm stainless steel wire and highly statistical significant in mean of 1.0mm. stainless steel wire . This means that the 0.6mm and 0.7mm have more corrosion resistance than 0.8mm and 1.0mm. This may be due to the corrosion depended on surface area that exposure to the solution (artificial saliva).Thase results are also mentioned in figure (2).

Table (5) mentioned the mean of corrosion rate of four gauges after calculating the corrosion according to corrosion rate formula(the change in weight on exposure area and time) ,showed that the 1.0mm stainless steel has more corrosion resistance followed by 0.8mm, followed by 0.6mm and finally by 0.7mm of stainless steel wire

The "ANOVa" test for corrosion rate in table (6) between groups and within group showed the statistical significant values ($p<0.005$).

The least significant difference (LSD) of multiple comparison test showed that o.6mm of stainless steel wire has non statistical significant compared with 0.7mm and 0.8mm but highly significant with 1.0mm ,This is due to the fact that (W_1&W_2) of 1.0mm .was more than 0.6 mm. stainless steel wire before and after corrosion .The 0.7mm has no significant difference as compared with 0.8mm but highly statistical significant with 1.0mm stainless steel but

0.8mm significant as compared with 1.0mm stainless steel wire. This results is in an agreement with [17]. They found that the large surface area provided by wire surface provided favorable environment for growth of bacteria and led to corrosion.

There are different forms of corrosion occur in the alloy , Uniform Corrosion , Pitting Corrosion, Crevice Corrosion, Fretting and Erosion-Corrosion , Intergranular Corrosion, Galvanic Corrosion of Orthodontic Alloys, Stress Corrosion of Orthodontic Wires, Hydrogen damage,and Microbial Corrosion [18], microscopic anaylsis of the metal surface also used to detect the types of corrosion [19]. In this study, the type of corrosion was pitting corrosion type of all gauges of wire was examined by microscope (x4 magnification).fig (8)& (9)
This result in this study is in an agreement with [16] but in disagreement with [19], they found that the most type of corrosion was crevice corrosion.

Potentiodynamic polarization experiments and scanning electron microscopic oberservations of arch wires composed of stainless steel, CoCr, NiCr, NiTi and Beta-Ti exposed to electrochemical corrosion in artificial saliva have shown evidence of pitting corrosion formed on the wire surfaces.[20]

Pitting corrosion is a sharply localized corrosion occurring on base metal such as iron, nickel & chromium, which are protected by a naturally thin film of an oxide .In the presence of chlorides in the environment, the film locally breaks down and has rapid dissolution of the underlying metal occurs in the form of pits or holes. This may be isolated or closed together that they look like a rough surface and the occur within or at the grain boundaries of alloy.[18,21]

Conclusions

On the basis of the results arrived at, the following conclusions can be drawn:
1- There is no statistically significant difference in mean corrosion value of 0.6mm. stainless steel wire group (group A) also in group (B) 0.7 mm. stainless steel wire .
2- Statisticaly significant difference in mean corrosion value of 0.8mm. stainless steel group (group C) and highly significant difference in mean corrosion value of 1.0mm. stainless steel group (group D).
3 –Statistically significant difference in mean corrosion rate value was observed of different group with different gauge and the best outcome of corrosion resistance were found for the 1.0mm group and low corrosion resistance was found in 0.7 mm .group.
4- The type of corrosion of different group with different gauge was pitting corrosion.

References

1- Phillips, R.W. (1973), Science of dental materials .7th .255.
2- Kusy, R.P.A. (1997), " Areview of contemporary arch wires: their properties and chanceries tic .Angle orthod : 67 :197 – 207 .
3- Al- Hiyasat, A.S.; Bashabsheh; O.M. and Darmni, H. (2003) :Elements release from dental casting alloys and their cytotoxic effect .Int.J prosthodent .16:8-12
4- Geis –gerstorfer, J.;Weber, H. (1987): "In vitro corrosion behavior of four Ni/Cr dental alloy in lactic acid and sodium chloride solution .dent matter : 3:289.295 .
5- Anusavice, K.J. (1996) , "Philip's science of dental material " 10^{ed} " Philadelphia , sounders ch 14 : 315 - , ch 15 : 327 – 346 , ch 16 : 347 – 359 , ch 20 : 423 – 459 , ch 23 : 491 -524 , ch 27 : 619 – 630.
6. Jia, W.; Beatty, M.W.; Reinhardt, R.A.; Petro, T.M.; Cohen, D.M.; Maze, C.R.;Strom EA, and Hoffman, M. (1999),Nickel release from orthodontic arch wires and cellular immune response to various nickel concentrations. J Biomed Mater Res. 48:488–495.
7. Kerosuo, H.; Moe, G.and Kleven, E. (1995), In vitro release of nickel and chromium from different types of simulated orthodontic appliances. Angle Orthod. 65:2111–116.

8. Iijima, M.; Endo, K.; Ohno, H.; Yonekura, Y. and Mizoguchi, I. (2001),Corrosion behavior and surface structure of orthodontic Ni-Ti alloy wires. Dent Mater J. 20:1103–113.
9. Maruthamuthu ,S. et al(2005), electrochemical behavior of microbes on orthodontic wires. urrent Science, 89(6).
10-Luthy, H.;Marinceello, C.P; Reclarn L, Scharer P. (1996). "Corrosion consideration in the brazing repair of Co/Cr based PD". J prosthetics dent: 75:515 -524.
11-Humphrey, S.P., and Williamson, R.T. (2001):"A review of saliva normal comparison,flow and function" J prosthetic dent; 85: 162-169.
12- Moberg, L.E.(1985), Long – term corrosion studies in vitro of gold, Co/Cr, and Ni/Cr alloys in contact ". Acta dental Scand. 43:215-222.
13. Martinez, J.R. and Barker, S. (1987), Ion transport and water movement. Arch.Oral Biol. 32: 843-847.
14. Maijer, R.; Smith, D.C. (1986), Biodegradation of the orthodontic bracket system. Am Orthod Dentofac Orthop.; 90:195–198.
15. Brantley, W.A. (2001),Orthodontic wires. In: Brantley WA, Eliades T, eds. Orthodontic Materials: Scientific and Clinical Aspects. Stuttgart: Thieme,77–103.
16-Al-Hiyasat, A.S. and Darmani, H.(2005), the effect of recasting on the cytotoxicity of base metal alloy " J prosthet ; 93(2): 158-163.
17. Maruthamuthu,S.; Rajasekar,A.; Sathiyanarayanan, S. ; Muthukukumar,N.and Palaniswamy,N. (2005),Electrochemical behavior of microbes on orthodontic wires. Current Science, 89(6):988-996.
18-Noort, V. (2002): "Introduction to dental material" 2 ^{en} ed. 109:61-67
19-Platt, A. ;Guzmen, A.;Zuccari and Thornburg, W .(1997):"Corrosion behavior of 2205 duplex stainless steel " AMJ ortho Dentolac orthop ;112:69-79.
20. Barret,R.D.; Bishara, S.E. Quinn, J.K. (1993),Biodegradation of orthodontic appliancesPart I: biodegradation of nickel and chromium in vitro. Am J Orthod Dentofac Orthop103:8–14.
21- Benatti, O.F.M.; Miranda, W.J; Muench, A. (2000),In vitro and in vivo corrosion evaluation of Ni /Cr and copper aluminum-based alloy" J prosthetic Dent, 84 (3): 360 – 363.

Fig. (1) Wire with different gauge

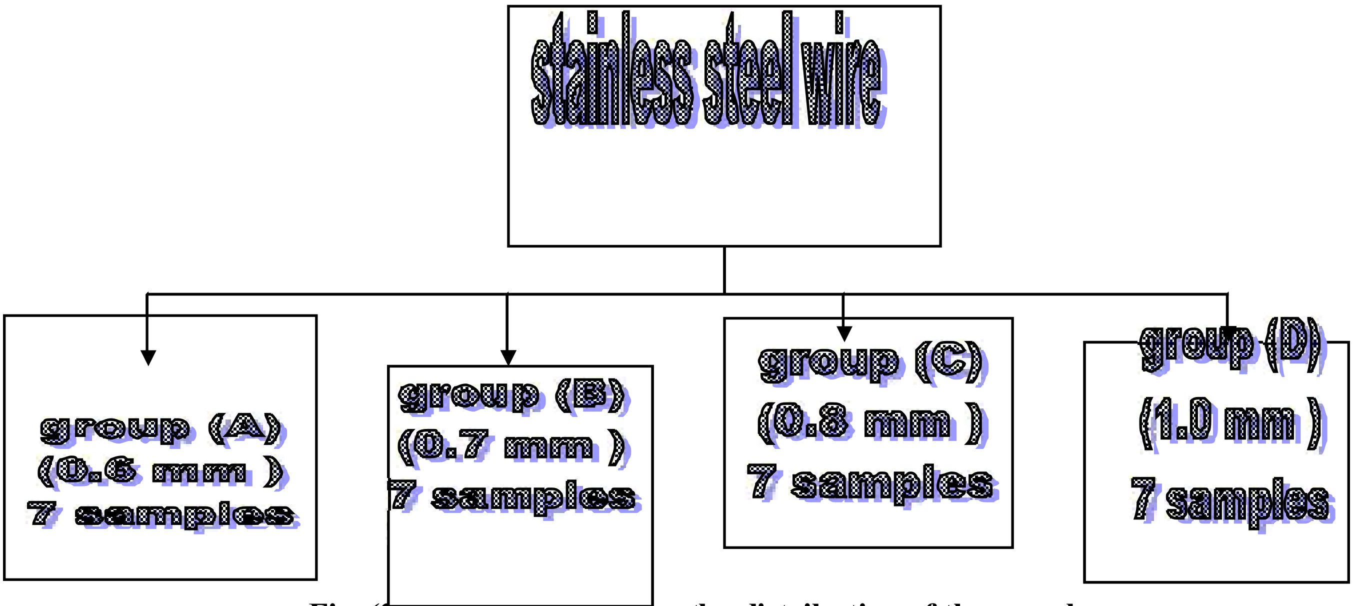


Fig. (2) Diagram illustrates the distribution of the samples

Fig. (3) The specimen & ruler

Fig.(5) Olympus photomicroscope device

Fig. (4) The specimen in Acetone Materials

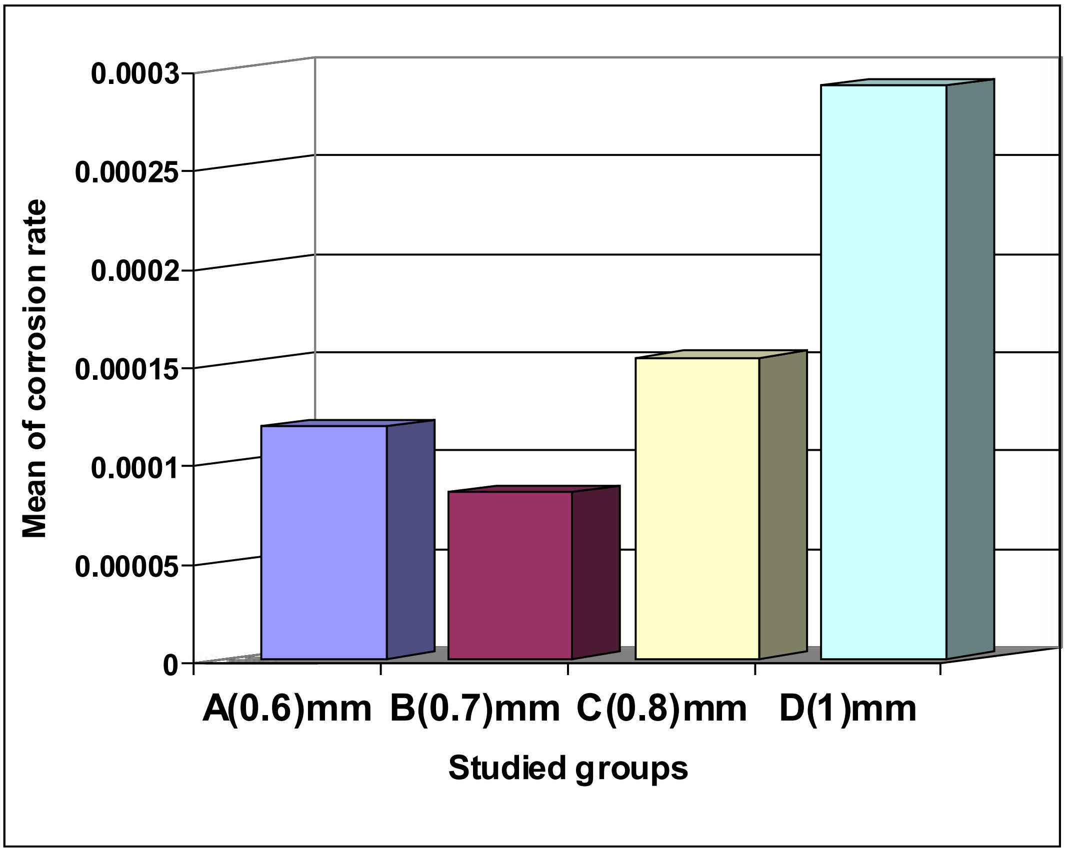


Fig. (6) Comparison between W_1 / mg (Before corrosion) & W_2 / mg (After corrosion) among studied groups

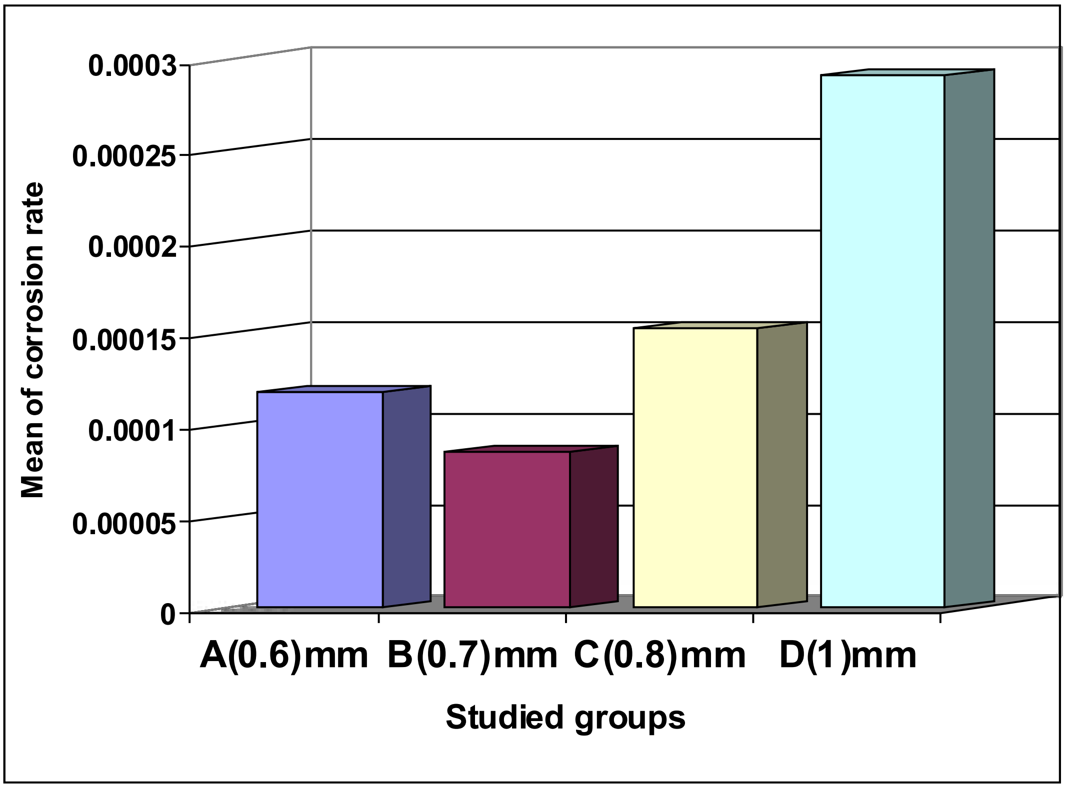
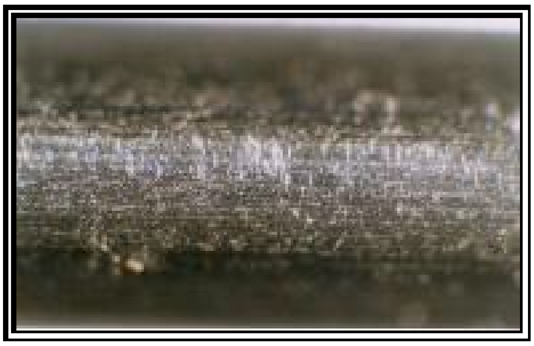


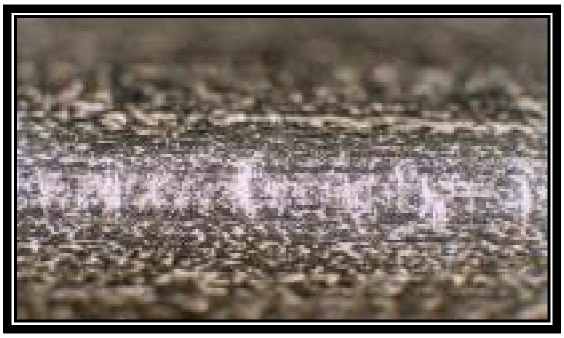
Fig. (7) Mean distribution of corrosion rate among studied groups



A

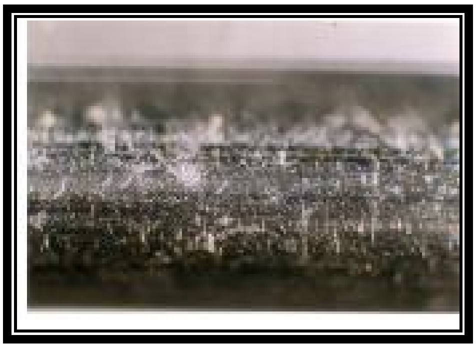
B

C

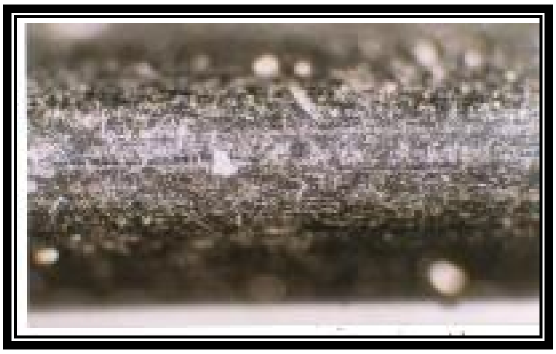


D

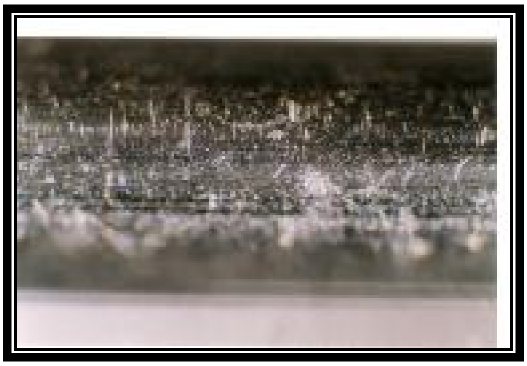
Fig. (8) Stainless steel wire under microscope before corrosion
(a :0.6mm;B:0.7mm; C :0.8mm ;D:0.9mm



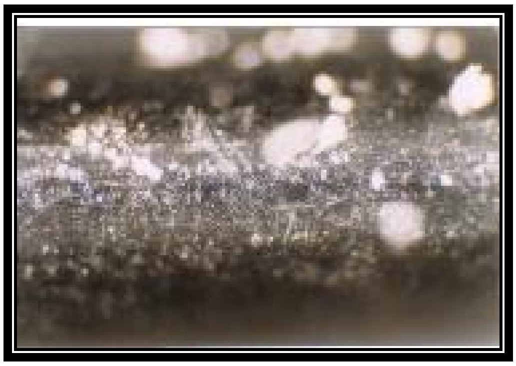
A



B



C



D

Fig. (9) Stainless steel wire under microscope after corrosion
(a :0.6mm;B:0.7mm; C :0.8mm ;D:0.9mm)

Table (1): Composition of artificial saliva used in this investigation

Element	Composition in gm/ml
Nacl	0.4
KCl	0.4
$CaCl_2.2H_2O$	0.795
Na H_2PO_4	0.69
Urea	1.0

Table (2): Mean distribution of W_1 / mg (Before corrosion) among studied groups

Studied groups	No.	Mean	Std. Dev.	Std. Error	Mini.	Maxi.
A (0.6 mm)	10	0.021	0.0006	0.0002	0.0208	0.0223
B (0.7mm)	10	0.030	0.0001	0.00006	0.0300	0.0305
C (0.8mm)	10	0.038	0.0002	0.0001	0.0381	0.0390
D (1.0mm)	10	0.051	0.0012	0.00047	0.0494	0.0530
Total	40					

Table (3): Mean distribution of W_2 / mg (After corrosion) among studied groups

Studied groups	No.	Mean	Std. Dev.	Std. Error	Mini.	Maxi.
A (0.6 mm)	10	0.0207	0.000567	0.000214	0.0200	0.0218
B (0.7 mm)	10	0.0294	0.000195	0.000073	0.0292	0.0297
C (0.8 mm)	10	0.0369	0.000267	0.000101	0.0366	0.0372
D (1.0mm)	10	0.0469	0.00199	0.000752	0.0425	0.0481
Total	40					

Table (4): Comparison between W_1 / mg (Before corrosion) & W_2 / mg (After corrosion) among studied groups

Gauge of wires (groups)	ΔW	No.	Mean	Std. Dev.	Std. Error	Mini.	Maxi.
A (0.6 mm)	W_1	10	0.021	0.0006	0.0002	0.0208	0.0223
	W_2	10	0.0207	0.000567	0.000214	0.0200	0.0218
	Total	20	P-value (0.968) Non Sig. (P>0.05)				
B (0.7mm)	W_1	10	0.030	0.0001	0.00006	0.0300	0.0305
	W_2	10	0.0294	0.000195	0.000073	0.0292	0.0297
	Total	20	P-value (0.973) Non Sig. (P>0.05)				
C (0.8 mm)	W_1	10	0.038	0.0002	0.0001	0.0381	0.0390
	W_2	10	0.0369	0.000267	0.000101	0.0366	0.0372
	Total	20	P-value (0.031) Sig. (P<0.05)				
D (1.0mm)	W_1	10	0.051	0.0012	0.00047	0.0494	0.0530
	W_2	10	0.0469	0.00199	0.000752	0.0425	0.0481
	Total	20	P-value (0.00) Highly Sig. (P<0.01)				

Table (5): Mean distribution of corrosion rate among studied groups

Studied groups	No.	Mean	Std. Dev.	Std. Error	Mini.	Maxi.
A (0.6 mm)	10	0.000118	0.000056	0.000021	0.00006	0.00020
B (0.7mm)	10	0.000085	0.000011	0.000004	0.00007	0.00010
C (0.8mm)	10	0.000153	0.000036	0.000013	0.00012	0.00021
D (1.0mm)	10	0.000291	0.000209	0.000079	0.00011	0.00075
Total	40					

Table (6): The ANOVA test for corrosion rate among studied groups

ANOVA test	Sum of Squares	dF	Mean Square	F	P-value	Sig.
Between Groups	0.0000002	3	0.00000006	4.700	0.012	Sig. (P<0.05)
Within Groups	0.0000003	24	0.00000001			
Total	0.0000005	27				

Table (7): The least significant difference (LSD) of multiple comparison tests for corrosion rate among studied groups

Studied groups		LSD (F-test)	
		P-value	Sig.
A (0.6mm)	B (0.7mm)	0.583	Non Sig. (P>0.05)
	C (0.8mm)	0.564	Non Sig. (P>0.05)
	D (1.0mm)	0.007	Highly Sig. (P<0.01)
B (0.7mm)	C (0.8mm)	0.265	Non Sig. (P>0.05)
	D (1.0mm)	0.002	Highly Sig. (P<0.01)
C (0.8mm)	D (1.0mm)	0.028	Sig. (P<0.05)

مجلة ابن الهيثم للعلوم الصرفة والتطبيقية المجلد23 (2) 2010

السلوك التآكلي في مختلف القياسات في السلك المقاوم للصدأ المستعمل في طقم الأسنان الجزئي المتحرك وأجهزة تقويم الأسنان

نضال صاحب منصور

هيئة التعليم التقني ، كلية التقنيات الصحية والطبية

الخلاصه

تستعمل الأسلاك بشكل شائع لصناعة اجهزه تقويم الأسنان وكمشابك في صناعة طقم الأسنان الجزئي. أن مقاومة التاكل تعتبر من الصفات الاكثر اهميه في سبيكة الأسنان لما لها من تاثير سلبي على انسجة الجسم الحيه وجهاز الأسنان نفسه .كما أن الظروف في الفم مناسبه جدا لحدوث عملية التأكل، الهدف من هذه الدراسه تقيم سلوك التأكل في اربع قياسات من الحديد المقاوم للصدأ في اللعاب الصناعي. حضرت اربع قياسات من السلك المقاوم للصدأ المستعمل في تقويم الأسنان المتحرك وطقم الأسنان الجزئي وقسمت طبقا" للقياس الى اربع مجاميع (A,B,C,&D) عشرة عينات في كل مجموعه طول كل عينه (واحد سنتميتر) ،حضر اللعاب من نوع (Fusayam mere) كمحلول للاختبار واستخدم ميزان الكتروني حساس لوزن العينه قبل الغمر في اللعاب الصناعي وسجلت تلك القراءه كوزن اولي (W_1) بعد ذلك وضعت كل عينه في وعاء وعلقت بخيط من البلاستك (خيط تنظيف الاسنان)لضمان غمر العينه بالكامل ومن كل الجهات ثم وضعت في حاضنه بدرجه حراره ٣٧+_ ٢ولمدة (١٤) يوم ازيلت تلك العينات وتركت تجف ثم وزنت كل عينه بنفس الجهاز وسجلت كقراءه ثانيه (W_2) ، وبعد الحصول على الوزن الاول والثاني واخراج الفرق بين الوزن لكل عينه كانت النتيجه ٦ ،٠مليمتر و ٠،٧مليمتر اكثر مقاومة للتاكل من الاحجام الاخرى ، وكذلك احصائيا" وجد ا الأختلاف في الوزن كان كبيرا" في ٠،٨ملميتر و ١،٠ ملميتر . وعند تطبيق معادله التاكل وجد احصائيا" ان (٠،٨ ملميتر ١،٠ ملميتر)اكثر مقاومة للتاكل من ٦,٠ملميتر و ٠،٧ملميتر.