Original Article

Effects of Different Mediums on the Surface Topography and Corrosion of Dental Implant Abutment

Ayesha Tariq Niaz[1], Ali Dad Chandio[2], Amynah Charania[3], Shafaq Saeed Roghay[4], Khusbu Lohana[4] and Zaeem Arif Abbasi[1]

ABSTRACT

Objective: To compare the effect of artificial saliva, carbonic drink and gutka extracts on the surface topography, corrosion kinetics and hardness of dental implant abutment.

Study Design: In-vitro experimental study

Place and Duration of Study: This study was conducted at the NED University of Engineering & Technology and Karachi University from January 2019 to October 2019.

Materials and Methods: Abutments were tested for chemical composition, hardness, surface topography, characterization of microstructural constituents and weight loss/gain at 6 and 12-weeks by atomic absorption spectroscopy and electron dispersive spectroscopy.

Results: Electron dispersive spectroscopy showed significant Aluminum (Al) loss in the carbonic sample at 6 weeks' period ($p<0.05$). However, at 12 weeks, significant loss of Al ion ($p<0.05$) in carbonic drink and loss of Titanium (Ti) and Vanadium (V) ($p<0.05$) in gutka extract was observed. In atomic absorption spectroscopy after 6-weeks, gutka extracts showed significant rise in Ti ($p<0.05$) and Al ($p<0.001$) levels, whereas, in artificial saliva and carbonic drink, only the levels of V were found to be statistically significant.

Conclusion: Changes in surface topography and level of corrosion in dental implant abutments were found significant. Gutka extracts showed highest level of degradation and dissolution among all the mediums.

Key Words: Titanium alloy, artificial saliva, carbonic drink, gutka, corrosion, dental implant, abutments.

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INTRODUCTION

Loss of tooth due to dental caries, periodontal diseases or trauma is quite common. According to survey directed by National Health and Nutrition Examination Survey (NHANES) (1999-2004), between ages 20-34 years, the mean number of permanent teeth present were 26.90, whereas between 35-49 years it was 25.05 and between 50-64 years it was 22.30 (1).

1. Department of Oral Biology, Baqai Dental College, Baqai University, Karachi.
2. Department of Metallurgical Engineering, NED University of Engineering & Technology, Karachi.
3. Department of Oral Biology, Dr. Ishrat ul Ebad Khan Institute of Oral Health Sciences, Dow University of Health Sciences, Karachi.
4. Ziauddin Dental College, Ziauddin University, Karachi.

Correspondence: Zaeem Arif Abbasi, Baqai Dental College, Baqai University, Karachi
Contact No: 0321-3522414
Email: zaeemarif@hotmail.com

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Dentures, dental bridges and implants are the options offered for replacement of missing teeth. Dental implants are natural looking, biocompatible and stable compared to other dental prosthesis. Although implant is a costly procedure, but it stimulates and does not resorb the bone, as well as they tend to last longer, even a lifetime, which makes them very cost effective in general (2).

Implant failure can be attributed to corrosion, stress and presence of bacteria. Existence of corrosion products over the period may lead to the fracture of abutment, at the alloy-abutment interface or the body of the implant. Corrosion is also responsible for elements liberating from the material, toxic reactions, weak restoration, and surface roughing. The element liberation may discolor the surrounding tissues as well as contribute to allergic reactions ranging from oral edema, gingivitis, peri-oral stomatitis to extraoral manifestations such as eczematous rashes (3). It has been established that metal ions released due to corrosion leads to the pathomechanism of impaired wound healing (4).

In a study conducted on the Pakistani population, 90% of the young age population were consuming some kind of carbonic drinks with 51% consuming it daily(5). Due to increased consumption of this acidic beverage, it can be assumed that this may result in variations in implant or the abutment surfaces, which are susceptible to corrosion [6].

According to 2014 Global Adult Tobacco (GAT) survey done in Pakistan, gutka was found to be one of the most commonly used smokeless tobacco product (STP). It's a mixture of areca nut, powdered tobacco, slaked lime and artificial fragrances (such as menthol)[7].

In light of scientific evidence, it is being reported that the corrosive nature of Titanium (Ti) and its by-products, may have deleterious effects on the body. Importantly, medical and dental professionals should understand the implications, complexities, and potential pathways of exposure to these metals. There has been an in-depth research and study of this issue in orthopedics. On the other hand, there is lack of literature related to corrosion of dental implant abutments and its clinical implications, in the field of dentistry.

MATERIALS AND METHODS

Study Setting: Micro Vickers hardness testing and weight analysis of the samples were performed at the NED University**.** Atomic absorption spectroscopy (AAS), scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS), pH measurement and gutka extract preparation were performed at the Central Lab of Karachi University**.** Approval for the study was taken by the Institutional review board of Dow University (IRB-1056/DUHS/Approval/2018/144).

Inclusion and Exclusion Criteria: Screw retained abutment with gingival height 3 mm and abutment diameter & height of 4 and 5.5 mm, respectively, were included. Used, corroded or abutment with damaged surface were excluded.

Sample Size: Open Epi was employed to calculate the sample size (8) at 95% confidence level and 80% power. 21 dental abutments were taken, 3 abutments were assessed at the baseline and 3 abutments in each of the three experimental mediums.

Data Collection Procedure: Dental abutments were placed in artificial saliva (Biotene), carbonic drink (Pepsi) and gutka (JM) extracts over a period of 6 and 12 weeks. These abutments were covered with varnish except for the gingival margin (3mm) in order to expose the part of abutment actually in contact with the oral environment.

Sample Preparation: All the samples were weighed using weighing balance before and after immersion. 21 dental abutments (Neobiotech IS II active) and three mediums were used. 3ml of each medium was placed in a capped glass test tube and the dental abutments were immersed.

Gutka was first finely powdered using a mortar & pestle to obtain the extract. 20 g of powder was then dissolved in 50 ml of PBS (phosphate-buffered saline) and incubated at 37˚ C for 30 min after thorough shaking. The dissolved contents were filtered and quickly frozen at - 80℃ before undergoing lyophilization. Lyophilized extract was then reconstituted in 10 ml of distilled water and then utilized as one of the mediums [9].

Testing and Characterization: Before and after the corrosion study, each abutment underwent 10 indents to get a representative hardness using Microvicker hardness testing machine. pH was measured using a pH conductivity meter.

Qualitative and quantitative characterization of microstructural constituents of all the abutments were studied using SEM-EDS. Samples were loaded on the SEM for determination of the microstructures using different magnifications and fixed voltage of 15kV and for elemental analysis EDS detector was used.

Elemental analysis of the mediums was performed before and after the corrosion study by AAS. To calibrate the equipment, three standards of 2, 4 and 6 ppm were prepared from 1000 ppm standard of Fisher Scientific (UK) by serial dilution method using 1% HNO_3 as blank. After the calibration, the samples were injected into the equipment for analysis.

Statistical Analysis: Data was analyzed using SPSS v. 21. Paired t-test was used to assess the results of AAS, EDS, weight, pH, and hardness before and after the corrosion study for each element (Ti, Al and V) carried out in all three mediums. P-value of <0.05 was considered as statistically significant.

RESULTS

SEM images showed that the surface of dental abutment was mostly unaffected after 6-weeks in artificial saliva, whereas, there was slight surface oxidation at 12-weeks (Figure 1B & C). After immersion in carbonic drink, there was formation of oxide layer of various thicknesses and at certain locations had a network pattern (Figure 1D).

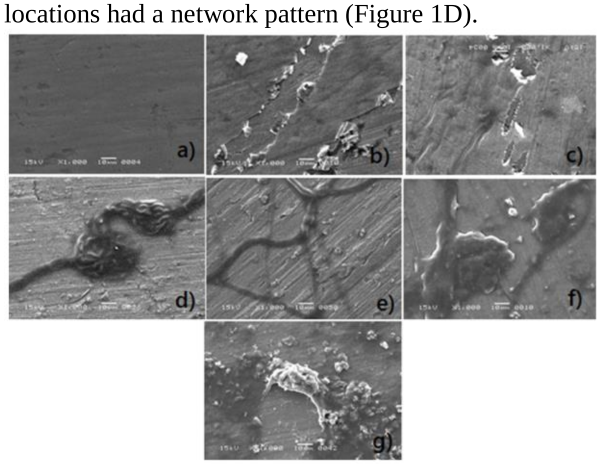

Figure No.1: Electron micrographs of dental abutment at high (1,000x) magnification; a) before immersion (control); After immersion in b) Artificial saliva (6-weeks); c) Artificial saliva (12-weeks); d) Carbonic drink (6-weeks); e) Carbonic drink (12-weeks); f) Gutka extract (6-weeks); g) Gutka extract (12-weeks)

As compared to results of immersion in artificial saliva and carbonic drink, dental abutment in gutka extract showed oxidation after 6-weeks and a thickened oxide layer formed after immersion for 12-weeks and subsequently giving banded appearance in some areas due to damaged/delaminated oxide layer (Figure 1F & G).

Though Ti is the main constituent of Ti-6Al-4V alloy, current study shows release of Al and V particles as well, after immersion in various medium. In a study, CP-Ti (commercially pure-titanium) showed better cell viability as compared to Ti, due to the presence of Al and V, with decreased cytotoxicity over a period of time due to the formation of TiO_2 (10).

Elution of ions from the Ti alloy caused the alteration in pH levels (Table 3) of all the study medium after the immersion process, another study reported similar results [11].

Table No.1: Mean weights before and after immersion in different mediums as seen with Electron dispersive spectroscopy (EDS).

		Mean (Weight %) at 6 - weeks		P-value	Mean (Weight %) at 12 – weeks		P-value
		Before	After		Before	After	
Artificial saliva	Ti	88.34	80.53	0.145	87.85	72.74	0.169
	Al	6.24	5.60	0.093	6.09	5.31	0.189
	V	3.37	2.27	0.502	3.37	1.67	0.263
Carbonic drink	Ti	88.34	86.31	0.109	87.85	86.31	0.542
	Al	6.24	5.06	0.012*	6.09	5.06	0.029*
	V	3.37	3.18	0.529	3.37	3.15	0.415
Gutka extract	Ti	88.34	61.50	0.082	87.85	31.10	0.049*
	Al	6.24	4.49	0.411	6.09	1.98	0.066
	V	3.37	1.96	0.529	3.37	1.05	0.017*

*Significant P value of < 0.05

Table No.2: Mean concentration of ion before and after immersion in different mediums as analyzed with Atomic absorption spectroscopy (AAS)

		Mean (µg/ml) at 6-weeks		P-value	Mean (µg/ml) at 12-weeks		P-value
		Before	After		Before	After	
Artificial saliva	Ti	0.759	6.313	0.226	0.759	15.76	0.005*
	Al	0.02	0.12	0.253	0.02	0.14	0.05*
	V	0.026	1.200	0.043*	0.026	3.812	0.026*
Carbonic drink	Ti	0.021	3.612	0.309	0.021	13.130	0.05*
	Al	0.14	0.23	0.255	0.14	0.007	0.044*
	V	0.048	7.546	0.021*	0.048	12.27	0.018*
Gutka extract	Ti	0.13	84.37	0.006*	0.123	144.02	0.069
	Al	0.07	1.01	0.001*	0.07	6.00	0.000*
	V	0.746	2.236	0.072	0.746	0.940	0.011*

* Significant P value of < 0.05

Table No.3: Effects of artificial saliva, carbonic drink and gutka extract on the hardness, pH and weight of the dental abutment at 6 and 12-weeks

		Mean (6-weeks)			Mean (12-weeks)		
		Before	**After**	**P-value**	**Before**	**After**	**P-value**
pH	Artificial saliva	6.06	4.77	0.007*	6.06	4.14	0.001*
	Carbonic drink	3.43	4.07	0.01*	3.43	4.44	0.029*
	Gutka extract	6.11	7.07	0.042*	6.11	6.46	0.163
Hardness (HV)	Artificial saliva	367.33	330.00	0.062	356.00	344.33	0.459
	Carbonic drink	367.33	337.00	0.017*	360.33	334.00	0.019*
	Gutka extract	355.67	338.67	0.075	358.00	352.00	0.027*
Weight (gm)	Artificial saliva	0.5658	0.5656	0.199	0.54	0.54	0.635
	Carbonic drink	0.5422	0.5420	0.603	0.54	0.54	0.803
	Gutka extract	0.5297	0.5276	0.029*	0.55	0.53	0.108

*Significant P value of < 0.05

DISCUSSION

SEM was used to analyze the surface of the experimented material. Faverani et al, reported that there was no significant corrosion in Ti-6Al-4V alloy when immersed in artificial saliva; in comparison, CP-Ti showed more corrosion [12]. pH of artificial saliva (6.06) is near to neutral; hence no significant damage is caused to the metal surface. Barão et al., reported that low pH caused significant corrosion of the dental implants, with severe effect in 2-3 pH solution [13].

Carbonic drinks have an acidic pH (2.5-3.5), that can easily cause corrosion of dental filling materials [14]. Despite the low initial pH of the carbonic drinks, the CO_2 gas was released after the bottle was opened, and H^+ ions were quickly lost. The pH could be elevated as a result, which possibly disables the capability of this liquid to attack the oxide layer on the surface. Encrustations that were formed on the surface of these groups observed by SEM were likely due to carbohydrates on the exterior of the Ti [15].

Increased concentrations of Ti ions engulfed by the osteoblasts near implant site, significantly reduces the osteoblast viability that would have detrimental effect on the implant stability[16]. Ti ions could influence osteoclasts differentiation by affecting the expression of Receptor activator of nuclear factor kappa-B ligand (RANKL) and osteoprotegerin (OPG) in osteoblastic cells [17].

In addition to the above-mentioned effects on hard tissues, Ti particles also have deleterious effects on the soft tissues. Combination of fibroblast from peri-implant granulation tissue in vitro with TiO_2 particles had a strong effect on gene expression of tumor necrosis factor- alpha (TNF-α), and production of TNF-α, interleukin (IL)-6 and IL-8, resulting in exacerbation of inflammation [18].

Al was found to affect cell proliferation and osteoblast metabolism to a lesser extent than Ti, as reported by an in-vitro study [19]. Though at higher concentrations afore-mentioned effects were enhanced. The current study reports that though Al ions were present in the mediums, released from the dental abutments, the concentration was very less to be able to exert any effect biologically as also suggested by another study [20]. An in-vitro study reported toxic potential of V on fibroblasts and osteoblasts growth when concentration of V was increased from 0.2 to 0.5 ppm [21].

Any change in the surface topography has an effect on other properties, such as loss of weight and decrease in the hardness of the alloy. Abutments and implants are manufactured to withstand fracture, fatigue, and wear to prevent failure of the prosthesis. Presence of a corrosive environment results in disintegration, leading to fatigue of the material and ultimately causing it to fracture [22].

Surface changes and corrosion promoted by the carbonic drink and gutka extracts used herein could induce the release of metal ions in the oral tissues around the implant affecting bone stability and implant prognosis. There is a minute release of alloying ions even under the ideal conditions that may cause damage to the abutment and/or implant.

Further longitudinal studies are required to determine the mechanical and chemical properties of the metal alloys used in manufacturing of dental implants and their abutments.

This being an in-vitro study, it had a limitation that experiment did not account of the physiologic environment of the oral cavity with its protective mechanisms and host response characteristics.

CONCLUSION

Though implants are becoming a common dental prosthetic alternative, dentists need to make sure that they inform their patients of the things that may cause harm to implant/abutment integrity so to prolong its life.

Author's Contribution:

Concept & Design of Study:	Ayesha Tariq Niaz
Drafting:	Ali Dad Chandio, Amynah Charania
Data Analysis:	Shafaq Saeed Roghay, Khusbu Lohana, Zaeem Arif Abbasi
Revisiting Critically:	Ayesha Tariq Niaz, Ali Dad Chandio
Final Approval of version:	Ayesha Tariq Niaz

Conflict of Interest: The study has no conflict of interest to declare by any author.

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