Review Article

DOI: 10.7860/JCDR/2019/41751.13088

Implant Abutment Screw Loosening: A Review of Effective Factors

Dentistry Section

MOHAMMAD ALI SEDDIGH[1], AZAM SADAT MOSTAFAVI[2]

ABSTRACT

One of the prevalent complications of dental implants is screw loosening. It has been revealed that screw loosening is a matter of concern for both manufacturers and dental professionals, and this complication imposes more time and money to clinician and patient. The clinical long-term success of implant restorations depends, in part, on the actions to minimise the parameters causing screw loosening. This review article aims to throw light on explaining these effective factors and parameters that determine screw stability. Literature based-search was performed to find related articles till December 2018 using EMBASE, Google Scholar and MEDLINE. Search terms used were Implant-abutment (I/A) connection/interface, screw-joint stability, lubricants (such as chlorhexidine (CHX), blood and saliva), mechanical and biological factors (such as contamination, micro-gap formation, settling effect, metal fatigue and abutment screw coating and loosening) in implant functional failure. Results were limited to papers available in English. The references of all related literature were also searched for further citations. A large number of factors including lubricants and mechanical factors have been proposed to have the potential of increasing screw loosening. In-vitro and in-vivo studies concerning the detailed role of biomechanical agents in incidence of screw loosening may be interesting area to improve the existing knowledge in this field. This paper presents the comprehensive insight into effective factors in incidence of screw loosening.

Keywords: Dental implant, Dental abutments, Dental restoration failure, Prosthesis loosening

INTRODUCTION

Over the decades, wide experience in implant knowledge has led to a growing success in implant dentistry rates up to ninety percent [1]. However, complications including biomechanical damage are still published in the literature [2]. It has been observed that screw loosening is a matter of concern for both manufacturers and dental professionals, and it is defined in the literature as one of the most frequent complications associated with dental implants and main causes of failure of implant-supported prosthesis, imposing more time and money to clinician and patient [3].

The reported rates of screw loosening may vary in various studies. Gunne J et al., reported that over a 3-year follow-up of patients, loosening of gold prosthetic screws was the most common mechanical failure, along with fracture of occlusal material [4]. In a similar study performed on patients with implant-retained prostheses for at least 5 years of follow up, 40% of gold slotted screws failed at the recall appointment [5]. In addition, a systematic review of the literature reported that incidence of screw loosening to be 12.7% over 5 years [6]. Ricciardi Coppedê A et al., also reported that 5.4% of abutment screws became unstable over the first year of function [7]. This difference may be due to different etiologic factors including mechanical or biological cause, implant components design and material.

Considering financial burden of screw loosening on the healthcare systems and patients, this review aims at explaining the effective factors which induces screw loosening. Literature based-search was performed to find related articles until December 2018 using EMBASE, Google Scholar and MEDLINE. Search terms used were I/A connection/interface, screw-joint stability, lubricants (such as chlorhexidine (CHX), blood and saliva), mechanical and biological factors (such as contamination, micro-gap formation, settling effect, metal fatigue and abutment screw coating and loosening) in implant functional failure. Results were limited to papers available in English. The references of all related literature were also searched for further citations. Subjects, abstracts, and the full text paper of the records retrieved from the databases were assessed for probable inclusion.

Lubricants

Implant-abutment (I/A) complex is an assembly gathered together by a screw. When an abutment is connected to the implant by tightening the screw, clamping forces are generated. The tension produced in the abutment screw upon tightening parallel to the implant axis, plus the tensile force along all the threads in contact, is called “preload” [8]. Silva-Neto JP et al., declared that preload is mainly important in preventing screw loosening [9]. Hence, if preload reduces during the clinical function, it may result in joint instability and screw loosening [10]. In considering this subject, reports have shown that dry implant cavity probably reduces preload during closing the abutment screw and consequently increases the risk of abutment screw loosening [11]. Nevertheless, few investigations have considered the important role of lubrication on amount of detorque and screw loosening [10,12].

The effect of lubrication with chlorhexidine (CHX) in I/A interface is not well understood. Gumus HO et al., reported that contamination by CHX before insertion of abutment has no statistically significant effect on Reverse Torque Values (RTVs) [13]. In addition, Asli HN et al., findings have shown that contamination of implant cavity with saliva and then with CHX increase the torque [11]. These data was similar to the results of Guda T et al., [14]. In another study carried out by Bulaqi HA et al., it has been revealed that use of lubricants like saliva could reduce the friction and consequently increase the preload [10]. Supporting Bulaqi HA et al., finding, other studies have shown that friction coefficient between the contact surfaces is one of the major factors which effects preload and for the same insertion tightening torque, decreasing coefficient of friction increases the preload value [15]. In other words, applied torque and preload are indirectly proportional to one another due to effect of friction and in fact, lower preloads were found in screws with increased coefficient of friction [16].

It is required to clarify how lubrication could have caused greater preload values. First, one probable explanation for process is that during screw tightening, friction is produced between the internal threads of implants and abutment screw threads. This friction is not distributed regularly. A humid media intervenes and definitely omits most of produced internal shear and tensile forces in threads. Second, while the abutment threads reach their final position inside the implant, specific areas on the sides of the threads could not be wetted by saliva. Thus, non-uniform friction would develop under separating forces resulting in greater amount of preload. Third, if the second reason is not confirmed, it is probable that wetting factor can contribute to more apical thread levels; Thus, there is no way for settling or embedment relaxation, and applied torque loss is negligible [17].

Unlike above data, Micarelli C et al., stated that these lubricants reduced the preload. This is also worth mentioning that, due to reduction of reverse torque following the use of CHX gel [18], Asli HN et al., showed that CHX gel alone (without saliva) was not as effective as a lubricant [11]. This data was in agreement with results of Micarelli C et al., [18]. In addition, Norton MR et al., reported that Reverse-torque values (RTVs) of titanium abutment screws is not increased by contamination with saliva [19]. The authors confirmed that saliva can decrease friction through penetration into microgaps on I/A interface and then depositing microorganisms and glycoproteins [20]. Differences in findings between mentioned studies can be due to differences in methodologies, variations in form (gel or liquid) and concentration of lubricants such as CHX, type of used screws like gold or titanium and repeated torquing at different times [13].

Despite the high risk, contamination by blood in the implant screw holes during clinical practice, particularly for bone level implants in surgery stages, there is limited study regarding contamination with blood in I/A interface in the published literature. Gumus HO et al., have found that blood contamination of abutment screw holes significantly decrease RTVs. They concluded that blood contamination can result in greater loosening of screws in clinical practice [13]. It is likely that blood contamination, because of high protein content and the presence of platelets or fibrinogen, can lead to the formation of a thin film on the surface of titanium screws. Another study has shown that attachment of blood cells to the implant surface immediately lead to interaction between them and blood accumulation on the metal surface may possibly have a negative effect on torque values [21].

Connection Types and Micro-Gap Formation

I/A connection in implant systems differ each other because of their structure, geometry, material properties, roughness, and several other features. Jaarda MJ et al., reported that screws produced by different manufacturers, even if they looked alike, could endure different maximum preload torque values before loosening [22]. Characteristic differences among screws with the same design and geometry can be attributed to manufacturing processes and different intrinsic material properties. Even screws made by the same manufacturer but from different lots, show different tensile stability [22]. Ideal connection system should act as a one-piece implant without micro-gap formation at I/A interface. Microgaps formation between the surfaces of implants and abutments is important for their biomechanical failures such as screw loosening [23]. External and internal hexagon systems have shown different amount of micro-gap [24]. Some researchers confirm that external hexagon systems are more prone to screw loosening [25]. Theoretically, internal hexagon systems indicate higher stability, better distribution of clamping forces under mechanical loading and elevated resistance to lateral loads [26]. The worst drawback of external hexagon connection system is the mechanical behaviour when exposed to tension forces different from the axial. This disadvantage causes a micro-gap at I/A connection and subsequently a mechanical instability in the complex [27]. Several researchers studied this condition and it is adequately clear that this micro-gap causes screw loosening [28, 29]. Micro-gap is rigorously related to the strength applied to the abutment that is why external hexagon connection system should not be used in case of functional overload [30] such as bruxism or clenching. Internal connection systems were improved as an evolution of the external hexagon system, to decrease or ultimately eliminate the micro-movement at the abutment connection level and increasing load absorption especially under a lateral force [24]. Therefore, theoretically internal hexagons have decreased biomechanical complications such as screw loosening.

Settling Effect

Another important mechanism that leads to screw loosening of implant-supported prosthesis is the settling effect. The settling effect or embedment relaxation is the result of no surface being completely smooth. No matter how precise the machined surface of implant is, it is somewhat rough from a microscopic viewpoint during manufacturing. Because of this microroughness on the surface of implant components, no two surfaces are completely in intimate contact with one another between the screw threads and the implant bore threads [31]. Settling of the screw occurs as the high rough spots flatten under load, since spots will be the only contacting surfaces when the initial tightening torque is applied. When the screw interface is subjected to external loads, micro-movement takes place between the surfaces in contact, wearing the contact parts and leads to closer approximation of the two surfaces. It has been observed that up to 10% of the initial insertion torque is lost because of settling effect [32]. for this reason, removal torque is usually lower than tightening torque [33]. The amount of settling depends on the surface hardness and roughness, and loading forces. When the total settling effect is higher than the screw elastic elongation, the screw loosening occurs because of the lack of contact surface forces to hold it in place [31]. Bakaeen LG et al., revealed that untightening torque was almost 2 to 3 Ncm less than tightening torque for gold prosthesis-retaining screws [34]. Sakaguchi RL et al., observed 2% to 10% decrease in preload over the first few minutes after tightening due to the settling effect [32]. Siamos G et al., suggested that screws must be retightened 10 minutes after the application of initial torque [35]. A number of studies have also suggested tightening of screw after the initial torque and periodically thereafter [36]. This approach should be used as a routine procedure in clinics.

Metal Fatigue

Metal fatigue phenomena is possibly the most frequent cause of implant structural failure which occurs after cyclic loading at stress levels below the maximum elastic strength of the material. Patterson EA et al., stated that the fatigue life of a screw is about 20 years [37]. Most specialists recommend tightening a screw to the maximum preload conceivable, within the final tensile strength, to guarantee a long fatigue life. However, the delivery of over-tightening torque has been problematic clinically and may lead to elastic deformation [38]. Possible lack of precision or quality in the machining of parts involved in I/A connection, leads to metal fatigue and also affect the lack of exactitude in contact between parts at moment of ultimate torque application of the screw [39] and might also affirm a lower abutment performance.

Clockwise and Counter-Clockwise Twisting Moments

Chewing occurs with a regular pattern, but the direction is reversed in different areas of the oral cavity, which leads to different reversing twisting moments. For instance, during chewing on the right side from eccentric contact to condylar position, the right mandible bone moves inward and forward. The right mandibular teeth make a clockwise twisting moments on the opposite maxillary teeth [21,40]. Hence, a twisting and bending moment is counteracted by I/A connection. Since the most convenient way to screw loosening is reversing it, the direction of the twisting moment may be a significant key point. For instance, application of the counterclockwise twisting moment to a right-hand threaded implant would cause screw loosening. Implant prosthesis are under chewing patterns of vertical and horizontal force combinations, yet all these force components including the direction and magnitude do not have the same effect with regard to amount of material resistance and incidence rate of failure [21].

In a fatigue-testing study [41], the mechanical stability of the connection of the Straumann® ITI dental implant system with a Morse taper connection was tested under bending and counterclockwise (un-tightening) twisting movements. The observations showed no significant difference in the mechanical resistance properties between the connections. The authors concluded that the importance of the internal key mechanism is not only to provide contribution as an anti-rotational device during its function but also to ensure positional indexing. Another study revealed that there is no difference between clockwise and counterclockwise twisting moments on screw loosening [21].

Successive Loosening and Retightening

In routine clinical practice, it may be necessary to remove the prosthetic components numerous times in order to adjust the temporary restorations, perform impressions and ultimate adjustments. It is essential to determine whether repeated loosening and tightening of the screws affect their resistance to loosening. Theoretically, successive and repeated loosening and retightening leads to creation of smooth micro-irregularities of the contact surfaces thereby decrease the friction coefficient. This process increases the elongation of the screw consequently resulting in progressive increase in preload value [42]. After many cycles, the energy that was spent first to smooth irregularities would now be used to generate preload [12]. Apart from theoretical aspects, in the literature review, this subject is controversial. Several in-vitro and in-vivo studies confirmed this theory. For example, in an in-vitro experiment performed by Guzaitis KL et al., it was shown that coefficient of friction is decreased by modification of surface morphology due to successive screw joint opening and closing [43]. In addition, Tzenakis GK et al., suggested the use of a used screw [5]. They revealed a greater preload after repeating the use of the same screw 10 times. However, Weiss EI et al., assessed the removal torque value of the screw in 7 implant connection systems, throughout successive cycles (around 200) of tightening and loosening [44]. They recorded an immediate loss of 3 to 20% in all connection systems, and in the Brånemark system there was 20% torque loss in the initial cycle, 31% after five cycles, and 36% after fifteen cycles. Furthermore, Ortorp A et al., and Byrne D et al., found a decrease in preload value after sequential loosening and tightening cycles [45,46].

Abutment Screw Coating

Some researches indicated that greater preload may be achieved with coated screws [31]. Previous investigations [47] have also revealed that screws with an altered alloy have a lower coefficient of friction, which may lead to greater preload values. A metal with low strength, like pure gold, may play the same role as dry lubricant. In comparison with abutment screws without gold coating, it has been revealed that gold-coated screws under torque values of 12, 20, and 32 Ncm showed 26, 24, and 24% increase in preload value, respectively [48]. Byrne D et al., determined that all types of screw presented less preload value with repeated retightening, irrespective of insertion toque and abutment type, but the gold-coated screw still indicated greater preload values for all insertion torques [46]. Similarly, Stüker et al., reported that generated preload in gold-coated screws are 3 times higher than titanium-coated screws [16]. In addition, Martin et al. found that screws with Gold-Tite coating had a greater tightening rotation angle and higher value of preload than titanium alloy screws [47]. Moreover, compared with titanium abutment screws, tightening and rotation of gold coated abutment screws with torque values of 12, 20, and 32 Ncm increased to 73%, 76%, and 62%, respectively [49].

The abutment screw with tungsten carbide carbon coating decreased the friction level to provide a 10° greater rotational angle at 30 Ncm tightening torque in comparison with non-coated titanium alloy screws in implant connection systems [50]. Martin WC et al., and Lang LA et al., have concluded that to preserve the stability of the prosthetic I/A joints [47,48], coated titanium alloy screws with solid lubricants act better than non-coated titanium screws [51].

CONCLUSION

In spite of the remarkable evolution of implant systems, biological and mechanical complications still exist. Dental implants do functionally fail, generally due to screw loosening or fracture. It has also been revealed that screw loosening is a matter of concern for both manufacturers and dental professionals, and it is defined in the literature as one of the most frequent complications associated with dental implants and main causes of failure in implant-supported prosthesis. Therefore, it is strongly recommended to continue efforts to improve I/A systems in order to decrease the screw loosening. A large number of factors including lubricants and mechanical factors have been proposed to have the potential of increasing screw loosening. In-vitro and in-vivo studies concerning the detailed role of biomechanical agents in incidence of screw loosening may be interesting area to improve the existing knowledge in this field. Considering comprehensive insight into effective factors in incidence of screw loosening in this paper, it seems that this complication is preventable.

REFERENCES

[1] Sun HL, Wu YR, Huang C, Shi B. Failure rates of short (≤10 mm) dental implants and factors influencing their failure: a systematic review. Int J Oral Max Impl. 2011;26(4):816-25.
[2] Yuan K, Chen KC, Chan YJ, Tsai CC, Chen HH, Shih CC. Dental implant failure associated with bacterial infection and long-term bisphosphonate usage: a case report. Implant Dent. 2012;21(1):03-07.
[3] Cardoso M, Torres MF, Lourenço EJ, de Moraes Telles D, Rodrigues RC, Ribeiro RF. Torque removal evaluation of prosthetic screws after tightening and loosening cycles: an in vitro study. Clin Oral Implan Res. 2012;23(4):475-80.
[4] Gunne J, Jemt T, Lindén B. Implant treatment in partially edentulous patients: a report on prostheses after 3 years. Int J Prosthodont. 1994;7(2):143-48.
[5] Tzenakis GK, Nagy WW, Fournelle RA, Dhuru VB. The effect of repeated torque and salivary contamination on the preload of slotted gold implant prosthetic screws. J Prosthet Dent. 2002;88(2):183-91.
[6] Theoharidou A, Petridis HP, Tzannas K, Garefis P. Abutment screw loosening in single-implant restorations: a systematic review. Int J Oral Max Impl. 2008;23(4):681-90.
[7] Ricciardi Coppedê A, De Mattos MD, Rodrigues RC, Ribeiro RF. Effect of repeated torque/mechanical loading cycles on two different abutment types in implants with internal tapered connections: an in vitro study. Clin Oral Implan Res. 2009;20(6):624-32.
[8] Wang RF, Kang B, Lang LA, Razzoog ME. The dynamic natures of implant loading. J Prosthet Dent. 2009;101(6):359-71.
[9] Silva-Neto JP, Prudente MS, Carneiro TD, Nóbilo MA, Penatti MP, Neves FD. Micro-leakage at the implant-abutment interface with different tightening torques in vitro. J Appl Oral Sci. 2012;20(5):581-87.
[10] Bulaqi HA, Barzegar A, Paknejad M, Safari H. Assessment of preload, remaining torque, and removal torque in abutment screws under different frictional conditions: A finite element analysis. J Prosthet Dent. 2019;121(3):548.e1-e7.
[11] Asli HN, Saberi BV, Fatemi AS. In vitro effect of chlorhexidine gel on torque and detorque values of implant abutment screw. Indian J Dent Res. 2017;28(3):314-19.
[12] Arshad M, Mahgoli H, Payaminia L. Effect of repeated screw joint closing and opening cycles and cyclic loading on abutment screw removal torque and screw thread morphology: scanning electron microscopy evaluation. Int J Oral Maxillofac Implants. 2018;33(1):31-40.
[13] Gumus HO, Zortuk M, Albayrak H, Dincel M, Kocaagaoglu HH, Kilinc HI. Effect of fluid contamination on reverse torque values in bone-level implants. Implant Dent. 2014;23(5):582-87.
[14] Guda T, Ross TA, Lang LA, Millwater HR. Probabilistic analysis of preload in the abutment screw of a dental implant complex. J Prosthet Dent. 2008;100(3):183-93.
[15] Burguete RL, Johns RB, King T, Patterson EA. Tightening characteristics for screwed joints in osseointegrated dental implants. J Prosthet Dent. 1994;71(6):592-99.
[16] Stüker RA, Teixeira ER, Beck JC, Costa NP. Preload and torque removal evaluation of three different abutment screws for single standing implant restorations. J Appl Oral Sci. 2008;16(1):55-58.
[17] Nigro F, Sendyk CL, Francischone CE, Jr., Francischone CE. Removal torque of zirconia abutment screws under dry and wet conditions. Brazilian Dent J. 2010;21(3):225-28.

[18] Micarelli C, Canullo L, Baldissara P, Clementini M. Implant abutment screw reverse torque values before and after plasma cleaning. Int J Prosthodont. 2013;26(4):331-33.

[19] Norton MR. Assessment of cold welding properties of the internal conical interface of two commercially available implant systems. J Prosthet Dent. 1999;81(2):159-66.

[20] Duarte AR, Neto JP, Souza JC, Bonachela WC. Detorque evaluation of dental abutment screws after immersion in a fluoridated artificial saliva solution. J Prosthodont. 2013;22(4):275-81.

[21] Yao KT, Kao HC, Cheng CK, Fang HW, Yip SW, Hsu ML. The effect of clockwise and counterclockwise twisting moments on abutment screw loosening. Clin Oral Implan Res. 2012;23(10):1181-86.

[22] Jaarda MJ, Razzoog ME, Gratton DG. Comparison of “look-alike” implant prosthetic retaining screws. J Prosthodont. 1995;4(1):23-27.

[23] Sahin C, Ayyildiz S. Correlation between microleakage and screw loosening at implant-abutment connection. J Adv Prosthodont. 2014;6(1):35-38.

[24] Ceruso FM, Barnaba P, Mazzoleni S, Ottria L, Gargari M, Zuccon A, et al. Implant-abutment connections on single crowns: a systematic review. Oral Implantol. 2017;10(4):349-53.

[25] Melo Filho AB, Mendes Tribst JP, de Carvalho Ramos N, Luz JN, Neves Jardini MA, Souto Borges AL, et al. Failure probability, stress distribution and fracture analysis of experimental screw for micro conical abutment. Braz Dent J. 2019;30(2):157-63.

[26] Maeda Y, Satoh T, Sogo M. In vitro differences of stress concentrations for internal and external hex implant-abutment connections: a short communication. J Oral Rehabil. 2006;33(1):75-78.

[27] Cooper LF, Tarnow D, Froum S, Moriarty J, De Kok IJ. Comparison of marginal bone changes with internal conus and external hexagon design implant systems: a prospective, randomized study. Int J Periodont Rest. 2016;36(5):631-42.

[28] Vigolo P, Gracis S, Carboncini F, Mutinelli S. Internal-vs External-connection single implants: a retrospective study in an italian population treated by certified prosthodontists. Int J Oral Max Impl. 2016;31(6):1385-96.

[29] Meleo D, Baggi L, Di Girolamo M, Di Carlo F, Pecci R, Bedini R. Fixture-abutment connection surface and micro-gap measurements by 3D micro-tomographic technique analysis. Ann I Super Sanita. 2012;48:53-58.

[30] Nishioka RS, de Vasconcellos LG, de Melo Nishioka LN. External hexagon and internal hexagon in straight and offset implant placement: strain gauge analysis. Implant Dent. 2009;18(6):512-20.

[31] Mancini GE, AB G, Cura F, Ormanier Z, Carinci F. Efficacy of a new implant-abutment connection to minimize microbial contamination: An in vitro study. Oral Implantol. 2016;9(3):99-105.

[32] Sakaguchi RL, Borgersen SE. Nonlinear contact analysis of preload in dental implant screws. Int J Oral Max Impl. 1995;10(3):295-302.

[33] Jaarda MJ, Razzoog ME, Gratton DG. Effect of preload torque on the ultimate tensile strength of implant prosthetic retaining screws. Implant Dent. 1994;3(1):17-21.

[34] Bakaeen LG, Winkler S, Neff PA. The effect of implant diameter, restoration design, and occlusal table variations on screw loosening of posterior single-tooth implant restorations. J Oral Implant. 2001;27(2):63-72.

[35] Siamos G, Winkler S, Boberick KG. The relationship between implant preload and screw loosening on implant-supported prostheses. J Oral Implant. 2002;28(2):67-73.

[36] Bacchi A, Regalin A, Bhering CL, Alessandretti R, Spazzin AO. Loosening torque of Universal Abutment screws after cyclic loading: influence of tightening technique and screw coating. J Adv Prosthodont. 2015;7(5):375-79.

[37] Patterson EA, Johns RB. Theoretical analysis of the fatigue life of fixture screws in osseointegrated dental implants. Int J Oral Max Impl. 1992;7(1):26-33.

[38] Goheen KL, Vermilyea SG, Vossoughi J, Agar JR. Torque generated by handheld screwdrivers and mechanical torquing devices for osseointegrated implants. Int J Oral Max Impl. 1994;9(2)149-55.

[39] Binon PP. Implants and components: entering the new millennium. Int J Oral Max Impl. 2000;15:76-94.

[40] Gibbs CH. Jaw movements and forces during chewing and swallowing and their clinical significance. Am J Orthod Dentofac. 1982:2-32.

[41] Perriard J, Wiskott WA, Mellal A, Scherrer SS, Botsis J, Belser UC. Fatigue resistance of ITI implant-abutment connectors- a comparison of the standard cone with a novel internally keyed design. Clin Oral Implan Res. 2002;13(5):542-49.

[42] Butkevica A, Nathanson D, Pober R, Strating H. Measurements of repeated tightening and loosening torque of seven different implant/abutment connection designs and their modifications: an in vitro study. J Prosthodont. 2018;27(2):153-61.

[43] Guzaitis KL, Knoernschild KL, Viana MA. Effect of repeated screw joint closing and opening cycles on implant prosthetic screw reverse torque and implant and screw thread morphology. J Prosthet Dent. 2011;106(3):159-69.

[44] Weiss EI, Kozak D, Gross MD. Effect of repeated closures on opening torque values in seven abutment-implant systems. J Prosthet Dent. 2000;84(2):194-99.

[45] Ortorp A, Jemt T, Wennerberg A, Berggren C, Brycke M. Screw preloads and measurements of surface roughness in screw joints: an in vitro study on implant frameworks. Clin Implant Dent R. 2005;7(3):141-49.

[46] Byrne D, Jacobs S, O’Connell B, Houston F, Claffey N. Preloads generated with repeated tightening in three types of screws used in dental implant assemblies. J Prosthodont. 2006;15(3):164-71.

[47] Martin WC, Woody RD, Miller BH, Miller AW. Implant abutment screw rotations and preloads for four different screw materials and surfaces. J Prosthet Dent. 2001;86(1):24-32.

[48] Lang LA, Kang B, Wang RF, Lang BR. Finite element analysis to determine implant preload. J Prosthet Dent. 2003;90(6):539-46.

[49] Cantwell A, Hobkirk JA. Preload loss in gold prosthesis-retaining screws as a function of time. Int J Oral Max Impl. 2004;19(1):124-32.

[50] Park JK, Choi JU, Jeon YC, Choi KS, Jeong CM. Effects of abutment screw coating on implant preload. J Prosthodont. 2010;19(6):458-64.

[51] Saliba FM, Cardoso M, Torres MF, Teixeira AC, Lourenço EJ, Telles DD. A rationale method for evaluating unscrewing torque values of prosthetic screws in dental implants. J Appl Oral Sci. 2011;19(1):63-67.

PARTICULARS OF CONTRIBUTORS:

1. Department of Prosthodontics, Tehran University of Medical Sciences, Tehran, Iran.
2. Department of Prosthodontics, Tehran University of Medical Sciences, Tehran, Iran.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Azam Sadat Mostafavi,
End of North Kargar Street, Adjacent to the Atomic Energy Organization, High School of Dentistry,
Tehran University of Medical Sciences, Tehran, Iran.
E-mail: as-mostafavi@sina.tums.ac.ir

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Apr 10, 2019**
Date of Peer Review: **May 18, 2019**
Date of Acceptance: **Jun 18, 2019**
Date of Publishing: **Aug 01, 2019**