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Comparing Torque Loss in Standard Implants and Short Implants with Increased Vertical Cantilever Abutments: an In Vitro Study

Comparação da perda de torque em implantes padrão e implantes curtos com pilares cantilever verticais aumentados (in vitro)

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ABSTRACT

Objectives: With regard to the prevalence of abutment screw loosening (SL) and bone height reduction, particularly in the posterior regions of the jaws, as well as the contradictory issue of applying short implants instead of surgeries, along with all preparations associated with longer implants, the present study aimed to compare the amount of torque loss in short implants with increased vertical cantilever abutments and standard ones. **Material and Methods:** In this experimental study, a total number of 20 implants (MegaGen Implant Co., Ltd, South Korea) with 4.5 mm diameter including 10 short implants (7 mm) and 10 standard ones (10 mm) were utilized. Using a surveyor, fixtures were perpendicularly mounted in 13×34 mm resin for short implants and 19×34 mm resin for standard ones. The abutments of the same height but different cuff heights (2.5 mm for the standard implants and 5.5 mm for the short ones) were then tightened with 30 N.cm, via a digital torque meter. To compensate the settling effect, the abutment screw was re-tightened with 30 N.cm after 10 min. Upon applying 500,000 cycles at 75 N.cm and 1 Hz along the longitudinal axis on each sample, blind reverse torque value (RTV) was measured with a digital torque meter. The data were finally analyzed using Student's t-test. **Results:** Both groups experienced torque loss, but there was no statistically significant difference between the case and control groups in terms of abutment SL ($p = 0451$). **Conclusion:** Short implants seem to be a good mechanical alternative in emergencies with respect to torque loss and abutment SL.

KEYWORDS

Reverse torque value; Cyclic loading, Short implant; Screw loosening; Crown-implant ratio; Torque loss.

RESUMO

Objetivos: Considerando a prevalência de afrouxamento de parafuso dos pilares, redução da altura óssea especialmente nas regiões posteriores, a questão contraditória da aplicação de implantes curtos em vez de cirurgias e todos os preparos associados a implantes mais longos, este estudo buscou comparar implantes curtos com pilares cantilever verticais aumentados e implantes padrão na quantidade de perda de torque. **Material e métodos:** Neste estudo experimental, foram utilizados 20 implantes (Megagen, Coreia do Sul) com diâmetro de 4,5 mm, incluindo 10 implantes curtos (7 mm) e 10 implantes padrão (10 mm). A fixação foi realizada perpendicularmente em uma resina 13 × 34 mm para implantes curtos e uma resina 19 × 34 mm para implantes padrão, usando um topógrafo. Os pilares da mesma altura, mas com diferentes comprimentos de manguito (2,5 mm para os implantes padrão e 5,5 mm para os implantes curtos) foram apertados com 30 N, utilizando um torquímetro digital. Para compensar o efeito de sedimentação, o parafuso do pilar foi reapertado com 30 N após 10 min. Depois de aplicar 500.000 ciclos a 75 N e 1 Hz ao longo do eixo longitudinal em cada amostra, o valor de torque reverso cego foi medido com um medidor de torque digital. Os dados foram analisados pelo teste t de Student. **Resultados:** Todos os grupos tiveram perda de torque, mas não houve diferença estatisticamente significativa entre os grupos caso e controle em termos de afrouxamento do parafuso do pilar ($p = 0451$). **Conclusão:** Os implantes curtos parecem ser uma boa alternativa mecânica em emergências em termos de perda de torque e afrouxamento do parafuso do pilar.

PALAVRAS-CHAVE

Carregamento cíclico; RTV; Implante curto; Afrouxamento do parafuso, perda de torque.

BACKGROUND

Decreasing reverse torque value (RTV) and subsequent abutment screw loosening (SL), which occur more often within the first year, are of the major issues raised in regional attachment, leading to mechanical and biological failures and peri-implantitis [1]. Considering the concerns about bone resorption, its low vertical height, as well as known complications of its preparation [2-4], especially in the elderly affected with systemic diseases, and with regard to the verticalcantilever and its effects induced by usage of perforce longer abutments in short implants in order to achieve proper occlusion, it is established whether application of short implants for vertical bone resorption is as successful as conventional implants or not [5-8]. Despite short implant failure reported in the related literature, recent studies have suggested improvements in prognosis [2,7]. In addition, reduced primary stability of short implants as a common problem has been enhanced in some new investigations [9]. Accordingly, implant-related factors affecting RTV and subsequent abutment SL include connection and geometry of implant-abutment interface, position, crown anatomy, framework matching, screw design, bone volume and density, implant surface area, and applied force for abutment tightening [1,10,11]. In this respect, the consequences of SL, torque loss, and gap formation can be divided into three groups:

1) Biological problems e.g. peri-implant mucositis, peri-implantitis, crestal bone resorption, and bad breath;

2) Mechanical problems including abutment SL and fracture, abutment fracture, and implant body fracture;

3) Financial and time problems.

Although the elderly and patients with systemic diseases and bad bone conditions are the major candidates for short implant treatments, they are more prone to develop serious complications [8]. Several techniques have been thus far suggested for an appropriate RTV and possible reduction of SL, including accurate screw preload, screw position, reduction of torque forces, use of mechanical torque wrench, precise framework, proper fitting of components, sufficient number of implants, para-functional prevention, appropriate occlusal scheme, precise attachment of prosthetic components, centric occlusal contact, narrow occlusal surface, cusp slope flattening, as well as abutment height reduction [1,12]. Various studies have similarly investigated RTV, SL, micro-gap formation, mechanical and biological failure, dynamic loading effects on bacterial colonization, and cyclic loading influences on short implants [1]. However, there are fewer studies into RTV in connection with SL than standard implants since short implant is a new field of research, and there is not a certain crown-implant (C/I) ratio in this regard. In general, there is no specific rule for short implants regarding SL and C/I ratio [3,5,12]. This is because changes in C/I ratio and limitations of these implants in response to oblique forces make them subjected to torque loss, SL, and reduced survival rates, as cited in different studies [13]. In contrast, some investigations have reported this increased ratio insignificant [14], due to lack of lateral force assessment. Some studies have further suggested fixture length as a factor reducing RTV and SL, whereas some others have introduced the first 3-4 threads as the main controlling factors [1,12]. There are also different opinions about peri-implantitis in short implants, wherein some investigations have reported a lower bone resorption level than that in standard implants [13,15]. On the other hand, short implants with wide diameters are assumed more feasible than bone grafting [16]. Therefore, the present study explored the effect of cyclic loading on simulating chewing forces on RTV and SL in short implants in comparison with standard ones.

MATERIAL AND METHODS

With reference to previous studies in this line like study of Hnd Hadi Mohammed et al. [12] and using the option of two-sample t-test assuming equal variances of PASS 15 software and considering $\alpha = 0.05$ and $\beta = 0.2$, the average of the two groups is 14.5, 12.1 standard deviation equals to 1.7 μm so a total number of 20 implants (MegaGen Implant Co., Ltd, South Korea) with 4.5 mm diameter including 10 short implants (7 mm) as the case group and 10 standard ones (10 mm) as the control were used in this experimental in vitro study [17,18]. The applied implants were root-formed and at bone level with internal hex connections. Straight abutments with 4.5 mm diameter with the same 5.5 mm height but different gingival cuff heights (2.5 mm for the standard implants and 5.5 mm for the short ones) were also employed to simulate clinical situations as insufficient bone height and to achieve proper occlusion. Therefore, short implants generally had longer abutments.

Auto-polymerizing transparent acrylic resin (Meliodent, Heraeus-Kulzer GmbH, Wehrheim, Germany) was further utilized for bone simulation. The acrylic resins were accordingly prepared using molds with 13 mm height and 34 mm diameter for restoration of low height bones and molds with 19 mm height and 34 mm diameter for restoration of normal height bones [12] in order to simulate bone height differences as a clinical issue. The acrylic resin for all the samples was additionally prepared with a proper powder-liquid ratio according to the manufacturer's instructions. Then, the surveyor (J.M. Ney Co., Bloomfield, CT, USA) was employed to prepare the fixtures within the acrylic mold in an exact perpendicular position (90° to the horizon) [12].

The abutments were tightened to the implants once the resin blocks were tightened in the jig [12]. The abutment screws were also tightened using the digital torque meter (Lutron Electronic Enterprise Co., Taiwan) (Figure 1) according to the instructions with a force of 30 N.cm [11]. In order to compensate the settling effect, the abutment screws were re-tightened by the digital torque meter with a force of 30 N.cm after 10 min [1,12] (Figure 2).

Figure 1 - Digital torque meter was used for tightening, retightening and measuring the RTV.

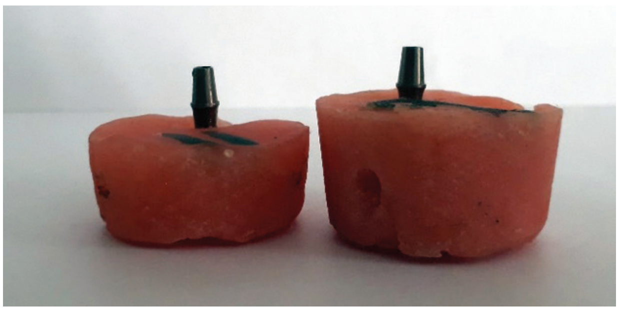

Figure 2 - Samples include short and standard implants are mounted and their abutments in different cuff heights are tightened.

The samples were coded from 1 to 20, (1-10 for standard implants and 11-20 for short ones). All the samples were then tested with a cyclic loading machine (Chewing Simulator CS-4, SD Mechatronik, Germany) to simulate the chewing forces and to apply a cyclic load of 75 N.cm with a frequency of 1 Hz at the longitudinal axis of each sample (perpendicular to the abutment surface) [5] (Figures 3A and 3B). Upon applying 500,000 cycles, equivalent to 20 months of chewing in the mouth, the samples were removed from the machine [1,16].

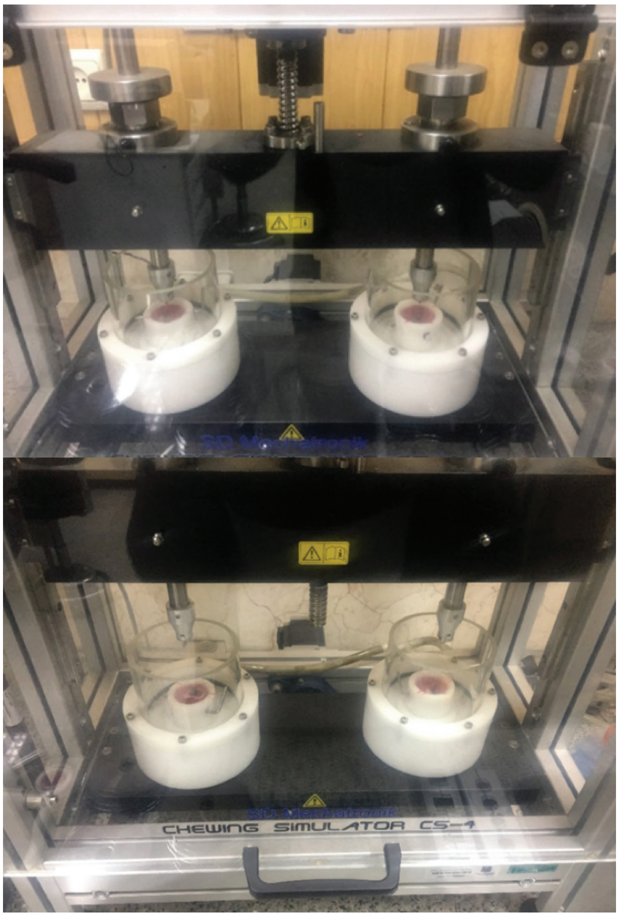

Figure 3 - The cyclic loading machine which simulates the chewing forces (A , B).

Ultimately, torque loss between the fixture and the abutment of each sample was blindly measured using the digital torque meter through recording the force required to open the abutment screw, and the obtained values were subsequently compared and the data were analyzed using Student's t-test.

RESULTS

This study aimed to measure torque loss and to compare RTVs in short and standard implants, assessed by the digital torque meter and the data collected, as follows (Table I).

Table I - Data collection. The blind reverse torque values of all short and standard implants had been measured with digital torque meter

No.	Standard types detorque	No.	Short types
1	17	11	19
2	25	12	12
3	26	13	20
4	17	14	20
5	15	15	13
6	30	16	20
7	35	17	19
8	14	18	21
9	14	19	32
10	21	20	21

The data with a normal distribution were analyzed using the IBM SPSS Statistics software (version 25) through Student's t-test. Both short and standard implants showed torque loss and decreased RTVs. The RTVs of the short implants were by 19.70 ± 5.37 N.cm and those for the standard ones were 22.40 ± 9.68 N.cm, but the results demonstrated no statistically significant differences between the case and control groups (p = 0.451) (Table II).

Table II - Comparison of detorque between control and case groups using t-test. Data showed, there is no statistically significant difference

Group	Mean ± SD	Minimum	Maximum	*p*-value
Control (n=10)	22.40 ± 9.68	14	35	0.451
Case (n=10)	19.70 ± 5.37	12	32	

DISCUSSION

Decreased RTV and SL, particularly within the first year, are the main problems facing abutments, which can also cause mechanical and biological problems as well as peri-implantitis [1]. The common problem associated with SL typically occurs in about 2-15% of the cases [19], most commonly in single-unit implants in the posterior regions of the jaws [1,6]. The main reasons in this respect are implant system, improper design and materials, inappropriate position, insufficient torque, and heavy occlusal forces [1,6,10,11]. There are, however, several techniques for overcoming SL including new materials and abutment screw designs for increasing preload, correcting screw preload, reducing torque forces, as well as improving central occlusal contact, narrow occlusal surface, and precise framework [1,12]. To mitigate the stress values in the posterior regions of the jaws rehabilitated with short implants, it is crucial to exploit a design to gain more bone-implant contact surface area, providing patients with a mutually protected or canine rise in occlusion and splinting implants together with no cantilever loads [17].

Another common problem is related to the vertical bone loss, especially in the posterior regions of the jaws [5,8]. Therefore, short implants that are easy to use and low-cost are an alternative solution for standard implants, which are associated with advanced surgical problems, including sinus lifting and nerve repositioning, with high costs and long-term treatments especially for the elderly suffering from systemic diseases [2,8,17]. In <7 mm length, the success rate of rough surface short implants have been also better than machined surfaces [17]. However, studies in this regard are fewer than those reflected on longer types, and there are even doubts about torque loss rate and C/I ratio in short implants [3,5,12]. Changes in this ratio and limitations of short implants in response to oblique forces can correspondingly reduce survival and increase loosening rate, but some studies have not considered this change in ratio as significant as possible [14]. With reference to some investigations, short length is deemed as a factor for reduced RTV, but some others have claimed that the first 3-4 threads are the main controlling factors [1, 12]. In some studies, bone resorption has been reported to be less in short implants than that in standard ones [13,15]. Consistently, it has been claimed that increased C/I ratios without any heavy occlusal forces does not lead to peri-implant bone loss [17].

This study was an experimental one aimed to compare torque loss in standard and short implants with increased vertical cantilever abutments in 20 samples, including 10 short implants (namely, case) and 10 standard ones (viz. control), to investigate the effects of implant length and C/I ratio on torque loss, to reduce RTV, and to increase SL. However, no significant difference was found between both groups in terms of torque loss. The insignificant torque loss and the reduced RTV may indicate the similar performance of short and standard types, confirming their acceptable use in emergencies. However, recent studies have suggested improvements in prognosis and success of short implants with better topography and adapted surgeries over time [6], but they still require long-term research considering other aspects [3,9] e.g. 94.5-100% of single-unit short implants have succeeded to empower and rehabilitate the posterior regions of the jaws for six years [20,21]. In spite of this, studies have not reflected on different aspects such as presence of antagonist teeth, number of single-unit short implants, and precise amount of bone loss [20,21]. According to Kim *et al.*, the amount of remaining torque could be affected by screw materials and it was by 77% in the titanium alloy [22]. In order to simulate the clinical problem in the present study, all the implants were titaniumbased with an internal hex connection and re-tightening, recommended for the internal types [1] and a longer abutment for short implants, increasing C/I ratio and simulating real clinical situations. With reference to the results, it seems that enhanced C/I ratio did not have a significant impact on further SL, which were consistent with the findings in the systematic study by Blanes *et al*., examining C/I ratio and its effects on implant-based restoration, wherein it was suggested that C/I ratio was not effective in bone resorption and restoration [15]. In a retrospective cross-sectional study, Schneider *et al*. had reviewed C/I ratio and clinical problems of single-unit implants in the posterior regions of the jaws, whose clinical results were in agreement with the findings of the present experimental study, indicating the ineffectiveness of changes in the C/I ratio [14]. Moreover, Renouard *et al*. had investigated the impact of implant length and dimensions on implant survival, and had further stated that, in contrast to previous studies regarding the failure of short implants, they had been successful and comparable to the standard types in recent studies [7]. The clinical study conducted by Hadzik *et al*. had additionally revealed the effects of the C/I ratios on crestal bone level and implant secondary stability, which had not been statistically significant but short implants could be successfully used [23]. A retrospective clinical study of Kim *et al*. had similarly claimed the same successful findings, in which survival and success rates had been respectively reported by 95.6% and 93.5% [18].

Survival could be definitely affected by several factors, but these studies were consistent with the present research regarding the similar effects of short and long implants.

Nevertheless, some investigations were not in agreement with the present study e.g. Ozyilmaz *et al*. examining short implants with different forces at various sites indicated that oblique forces were greater than axial ones. These stresses could be better tolerated by longer implants, meaning that the increased C/I ratio was associated with a higher stress, so that a longer crown and a shorter fixture could create more stress on the implant's body. As well, the abutment and the implant connection were also of importance [10], supporting the findings in the present study. The discrepancy of this research with previous studies can be attributed to differences in duration and amount of oblique forces and different implant systems used. It should be noted that the present study was an in vitro experiment in which only axial forces were simulated. In the study by Weng *et al*., 60% of the failed implants had been short ones less than 10 mm, and the success rate of the short implants had been significantly lower [24]. In addition, a systematic review by Telleman *et al*. had claimed that the shortest implants tended to fail in contrast with other short implants that were longer, and those in the maxilla could experience a greater failure rate [25]. This might come from the limitation of the present study in which the shortest implants were not examined. Herrmann *et al*. had also reviewed prognostic factors, showing low success rate of 78.2% for short implants with 7 mm length [26]. This inconsistency might be related to implant system, bone density, loads, surgical protocols, etc.

Also Siadat *et al*. had investigated the effect of different abutment heights on SL after cyclic loading, concluding that torque loss had increased with a growth in the abutment collar [27]. However, in the present study, there was no significant difference in the torque loss of the abutments with longer collars, which could be attributed to height and morse-taper shape of the abutments compared with the direct ones in the cited study.

Further research in the field of short implants seems necessary, because the existing studies are contradictory with regard to the success and failure of short implants. Therefore, all doubts should be examined in terms of different aspects in long-term in order to use short implants as an alternative in the case of necessity.

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Conflict of interest

The authors also declare no competing interests.

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