Effects of cyclic dislodgement on the retentive force reduction of different OT-Equator caps and removal torque of the retentive components of a mini dental implant system

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SUMMARY

Purpose. The aim of this study was to evaluate the retentive force and the removal torque of the OT-Equator® retentive components on mini dental implant under cyclic dislodgement at different angulations.

Methods. Fifty models of PW Plus® mini implants and OT-Equator® attachments were divided into 2 groups based on implant angulations (Group 1 = 0°, 2 = 15°). Each group was divided into 5 subgroups based on the weight-color coded of the retentive caps (black, yellow, pink, white and violet). Cyclic dislodgement was carried out for a total of 2,880 cycles. The retentive force was recorded at 0, 360, 720, 1,440 and 2,880 cycles. After the final cycle, the removal torque was measured. The data were analysed using One-way ANOVA and t-test with the significant set at $P < 0.05$.

Results. The increase in cyclic dislodgement significantly reduced the retentive force of OT-Equator® retentive caps at 15° compared to that at 0°, except for the black cap. The removal torque also significantly decreased after 2,880 cycle compared to the insertion. There were no significant differences in removal torque at different angulations.

Conclusions. Increases in the number of dislodgement cycles and implant angulation significantly decrease the retentive force of OT-Equator®. However, the implant angulation did not have significant influence on removal torque. OT-Equator® with increased implant angulation require regular follow-up each year and screw re-tightening should be considered.

Key words: cyclic dislodgement, implant angulation, removal torque, retentive force, mini implant.

Introduction

Severe maxillary and mandibular atrophy is considered as a poor health condition affecting quality of life due to compromising stability, support and retention of a removable denture, especially at mandible. Therefore, prosthetic management of mandibular edentulous arch has been challenging (1, 2). Implant-retained overdenture is an alternative treatment for patients who had undergone moderate to severe ridge resorption, which offers better esthetics, speaking ability, comfort, retention, and stability of the prosthesis. It also has some advantages over full arch fixed implant prostheses, such as fewer implants required and lower cost (3-5). A consensus statement from McGill University and the British Society for the Study of Prosthetic Dentistry stated that mandibular two-implant-retained overdenture was the first choice standard care of treatment (6, 7). Placement of the standard-sized implants to retain the full denture provides patient satisfaction. However, in case of patients with severe alveolar bone resorption, bone augmentation may be required for implant placement, with the consequence of an increase in costs and treatment time (8).

The use of mini dental implant (MDI) is frequently offered as an alternative treatment procedure in many cases of limited ridge anatomy. The glossary of oral and maxillofacial implants defined MDIs as "implant fabricated of the same biocompatible materials as other implants but smaller dimensions. Implant can be made as one piece to include an abutment designed for support and/or retention of a provisional or definitive prosthesis" (9). MDIs have diameters ranging from 1.8 to 3.3 millimeter and lengths ranging from 10 to 15 millimeter compare to standard-diameter implants which range from about 3.4 to 5.8 millimeter (10). They can be used in narrow atrophic edentulous ridge without bone augmentation. The advantages compared to standard size implants are that the technique is simple and involves minimally invasive surgery which preserves blood supply and bone height around the implants (11, 12). Therefore, it presents less complicated surgical morbidity, shorter healing duration and cost effectiveness of prostheses (12). The survival rate of MDI retained mandibular overdenture has been reported in the range of 81-97.4% after 3 years (12-14). Moreover, two and four MDIs have been reported to be immediately used successfully after a 1-year follow up for retaining lower complete dentures (15, 16). The clinical and radiographic peri-implant tissue responses of immediately loaded mini dental implants retained a mandibular overdenture were also found satisfactory after 3 years (14).

Various attachment systems have been utilized in order to achieve retention and stability of implant-overdentures. The selection of attachment systems should be considered regarding to jaw anatomy, mucosal ridge, oral function, long term outcomes of retention and prosthetic maintenance (17-20). Previous studies reported MDIs clinically used with bar and ball attachments (21, 22). Bar MDI-attachment systems for mandibular overdenture had better two-year survival rate (97.8%) when compared to ball attachment (90.0%) (22). Bar attachment provides more retention than ball attachment. However, bar design appeared to be technically sensitive in clinical and laboratory process. The prosthodontics maintenance requires higher cost with screw retightening and retainer adjustment (19). Ball attachment was considered the simplest design with favorable clinical outcomes. Nevertheless, gradual loss of retention was found to be the most common complication due to wear and damage of O-ring leading to replacement after 5 years of service (21). Stud attachments such as Locator (Zest Dental Solutions, Carlsbad, CA, USA) and OT-Equator (Rhein83, Bologna, Italy) have been widely used due to attachment height reduction, favorable magnitude and stress distribution (18, 23, 24). Locator attachments are available in different vertical heights. They are resilient, retentive, durable, and have some built-in angulation compensation. The repair and replacement are fast and easy. In addition, Locator attachments provide an adequate retention and better maintenance compared to ball and bar (19). Recently, OT-Equator attachments have been introduced for another low profile, small diameter (vertical height of 2.1 mm and diameter 4.4 mm) implant attachment supported removable denture which allowed implants divergence up to 30°. Implant assisted overdenture with OT-Equator can be used successfully without negatively affecting peri-implant tissue health (24). This form of attachment is affordable, simple use with various retention levels and easy for maintenance.

The success of implant-retained overdentures dominantly depends on the retentive capacity of its attachment component to maintain its long-term function. The movement between the retentive surfaces of an attachment during insertion and removal of the overdenture lead to wear and diminish retentive forces over time (25-29). In addition, the incidence of attachment loosening

was reported in 30% regarding prosthetic implant complications which seem to be a common problem after insertion. Abutment screw loosening lead to implant prosthesis movement and unfortunately screw fracture (29). This evidence might be due to functional load on attachment component. Besides, implant malalignment has been reported to influence both loss of retention and removal torque on attachment component after the function (26).
The retention and removal torque behavior of OT-Equator on divergence implant angulation of MDI after simulated function are lack of available information. Therefore, the aim of the present study was to evaluate the retentive force reduction and removal torque of OT-Equator attachment on mini dental implant in different angulation under cyclic dislodgement. The null hypothesis of this study was that there were no significant differences of retentive forces and removal torque among different retentive components of OT-Equator after insertion-removal cycles.

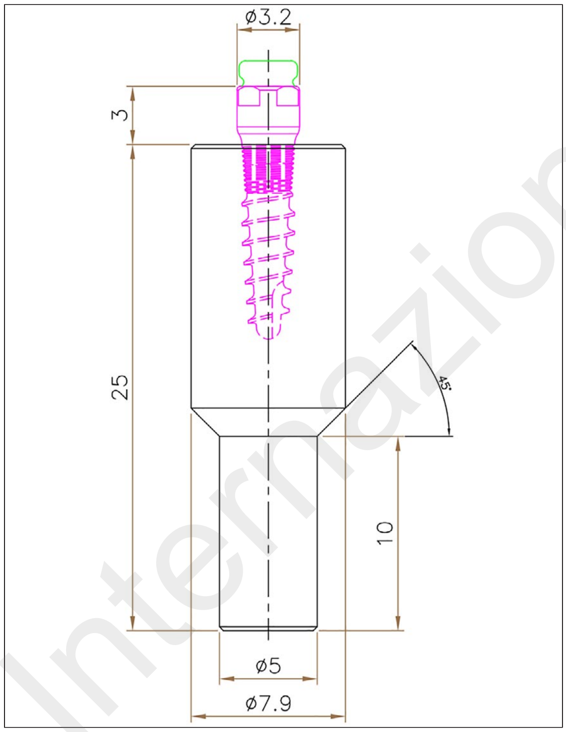

Figure 1
Schematic sketch of PW Plus® mini implant in resin block (Block A).

Materials and methods

Fifty PW Plus mini implants (PW Plus Co., Ltd., Nakorn Pathom, Thailand) diameter 3.0 mm and height 12 mm with conical implant-abutment connection were placed into the resin blocks (Block A) (Chockfast orange resin, Shannon Industrial Estate, Co. Clare, Ireland) with 0° angulation (Figure 1). The platform of the implant was at the same level of the resin block. Each OT-Equator abutment (Rhein83, Bologna, Italy) was screwed and tightened to each implant with a digital torque gauge (Tohnichi torque gauge, model BTGE50CN, Tohnichi Mfg. Co. Ltd., Tokyo Japan) to 25 Ncm following the instruction from the manufacturer. After ten minutes, all abutments were retightened with the same torque to reduce the settling effect.

OT-Equator metal housings with nylon caps were attached into the abutments. The customized metal blocks were placed over the metal housings and space reliefs were prepared. The metal housings were picked up in the customized metal blocks (Block B) (Figure 2) using auto-polymerizing acrylic resin (TOKUYAMA Rebase II, TOKUYAMA dental, Tokyo, Japan) mixed according to the manufacturer's instructions. The alignment of nylon cap-metal housing to the abutment-implant axis was set up at 0° with Universal Testing Machine (Instron 8872, Canton, MA, USA).
The model specimens were divided into 2 groups according to different implant angulation. There were group 1: 0° angle (n = 25) and group 2: 15°angle (n = 25). Each group consisted of 5 subgroups with different weight-color coded of nylon retentive caps (black; control, yellow; 0.6kg, pink; 1.2kg, white; 1.8kg, violet;

Figure 2
The customized metal block with OT-Equator® metal housing and nylon cap (Block B).

2.5kg) (Figure 3). Block A was attached into the fixed lower part of the testing machine which allowed to angulate the implant axis while Block B was positioned to the upper part. Each specimen group was tested under cyclic dislodgemen with the Universal Testing Machine (Instron 8872, Canton, MA, USA) with a frequency of 1 Hz and crosshead speed of 2 mm per milliseconds. The assembly was immersed in a plastic container filled with demineralized water at room temperature during the cyclic test (Figure 4).

The retentive force after insertion-removal cycles were recorded at simulated 3 months (360 cycles), 6 months (720 cycles), 1 year (1,440 cycles) and 2 years (2,880 cycles) of function with a number of four cycles per day. The retentive force and removal torque after cyclic dislodgement of each time intervals were investigated. The removal torque of attachment screw of all specimens after testing were measured with the digital torque gauge. After 2,880 cyclic dislodgement, all male attachment abutment were undergone for scanning electron microscopy (SEM) (JSM-5410LV, JEOL Ltd, Tokyo, Japan) inspection at magnification of ×35 for any damage or shape alteration.

Statistical analysis

All data were evaluated for normality test using Kolmogorov-Smirnov test. The retentive force of the different OT-Equator retentive caps over the different cycles was performed by One-way ANOVA. The retentive force and removal torque

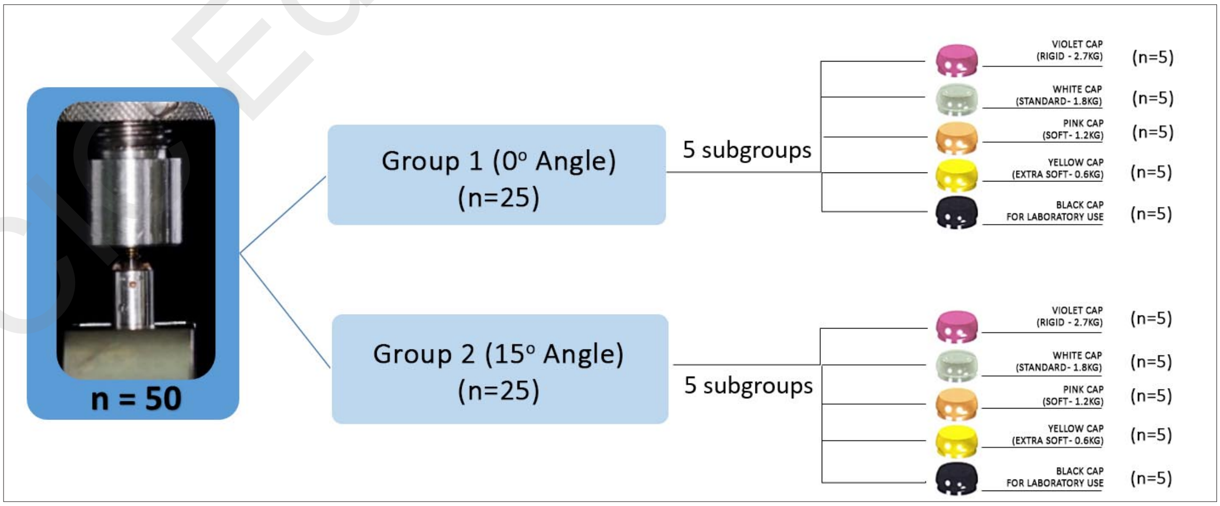

Figure 3
Schematic diagram for experimental procedure.

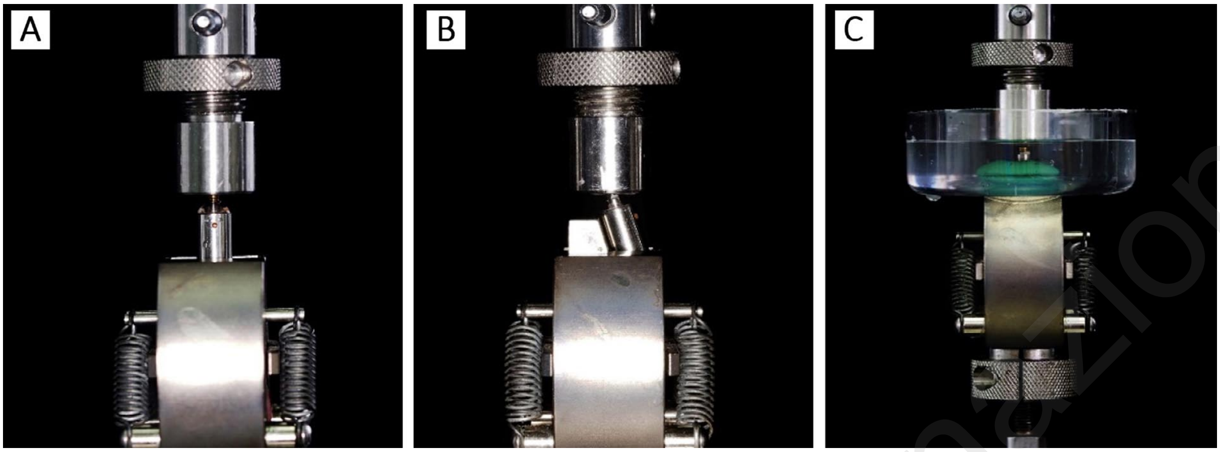

Figure 4
Experimental models simulation of cyclic dislodgement using universal testing machine; A: 0° angle, B: 15° angle, C: model immersed in deionized water.

reduction of different five OT-Equator retentive caps in two groups (0° and 15° angle) were compared using t-test. The comparison of the torque change between initial torque and removal torque of each OT-Equator retentive cap was done using t-test. A significant difference was considered at $P < 0.05$. The data were analyzed using SPSS 17.0 software (SPSS Inc., Chicago, IL, USA).

Results

Retentive forces

According to Kolmogorov-Smirnov test, the data were normally distributed. The mean retentive force (N) and standard deviation (SD) of different OT-Equator retention caps in different angulation under cyclic dislodgement were shown in Table 1. At the beginning of cyclic dislodgement (0 cycle), the different retentive forces of each color-coded retentive caps in both angulation at 0° and 15° were observed. For each subgroup, the black nylon exhibited the lowest initial retentive force, followed by the yellow, pink, white and violet nylon. Furthermore, the retentive forces at the baseline of all groups were found higher than those of the forces giving by manufacturer.

After cyclic dislodgement from the beginning to 2,880 cycles, both attachment angulations presented similar pattern of decreasing retentive force overtime (Figure 5). In each group of angulations, there were statistically significant differences of retentive force reduction overtime among each color-coded retentive cap (Figure 6). When compared between two angulations in each retentive group, there was no significant difference in black nylon group. However, there were significant differences in other groups ($P < 0.001$). The percentages of attachment retention loss in each group were calculated and compared to initial retention (0 cycle) (Table 2). The negative values indicated decrease in removal force.

Removal torque

All removal torque values in this study were normally distributed. The comparisons of removal torque of each group at the final and the initial

Table 1 - Mean retentive force and standard deviation (SD) of different attachment groups under cyclic dislodgement.

Attachment group	Mean retentive force (N) ± SD					
	cycle					*P*-value*
	n = 0	n = 360	n = 720	n = 1440	n = 2880	
Angulation 0°						
black	6.16 ± 0.44[a]	5.11 ± 0.35[b]	4.53 ± 0.34[bc]	3.84 ± 0.62[cd]	3.49 ± 0.67[d]	< 0.001
yellow	9.61 ± 0.21[a]	8.74 ± 0.19[b]	8.10 ± 0.27[c]	6.58 ± 0.28[d]	5.60 ± 0.44[e]	< 0.001
pink	17.71 ± 0.38[a]	15.51 ± 0.64[b]	13.32 ± 0.49[c]	11.88 ± 0.71[d]	10.68 ± 0.68[e]	< 0.001
white	21.30 ± 1.08[a]	17.88 ± 0.79[b]	15.84 ± 1.04[c]	12.05 ± 0.96[d]	11.02 ± 0.82[d]	< 0.001
violet	33.24 ± 1.52[a]	29.54 ± 0.66[b]	26.93 ± 0.44[c]	24.80 ± 0.71[d]	21.95 ± 0.86[e]	< 0.001
Angulation 15°						
black	4.73 ± 0.30[a]	4.37 ± 0.21[ab]	4.21 ± 0.24[b]	4.21 ± 0.22[b]	4.07 ± 0.19[b]	= 0.002
yellow	7.3 ± 0.23[a]	6.47 ± 0.78[ab]	5.44 ± 0.36[c]	4.77 ± 0.38[cd]	4.20 ± 0.21[d]	< 0.001
pink	14.18 ± 0.23[a]	12.56 ± 0.38[b]	9.87 ± 0.49[c]	9.03 ± 0.52[d]	6.97 ± 0.22[e]	< 0.001
white	16.48 ± 0.59[a]	14.02 ± 0.52[b]	11.07 ± 0.42[c]	8.58 ± 0.46[d]	7.06 ± 0.36[e]	< 0.001
violet	20.89 ± 0.68[a]	17.12 ± 0.44[b]	14.25 ± 0.26[c]	10.24 ± 0.49[d]	8.68 ± 0.27[e]	< 0.001

**P*-values were calculated using One-way ANOVA test.
Means with different lower-case letters (a, b, c, d and e) in each row showed significant differences using Tukey's HSD ($P < 0.05$).

cycle are shown in Table 3. From initial insertion torque of attachment (25 NCm.), the removal torques after 2,880 cycles were reduced significantly when compared to the initial insertion

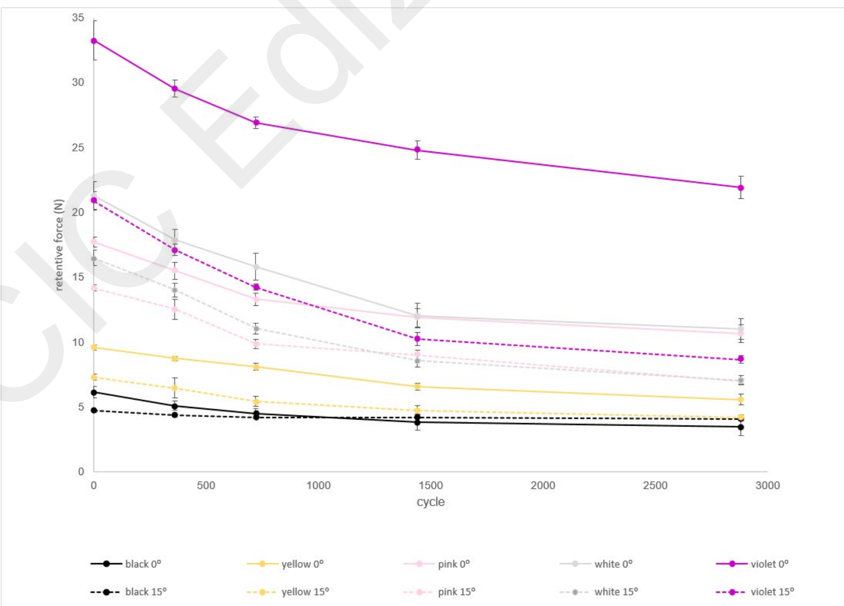

Figure 5
Mean retentive forces of different attachment groups in different angulations under cyclic dislodgement.

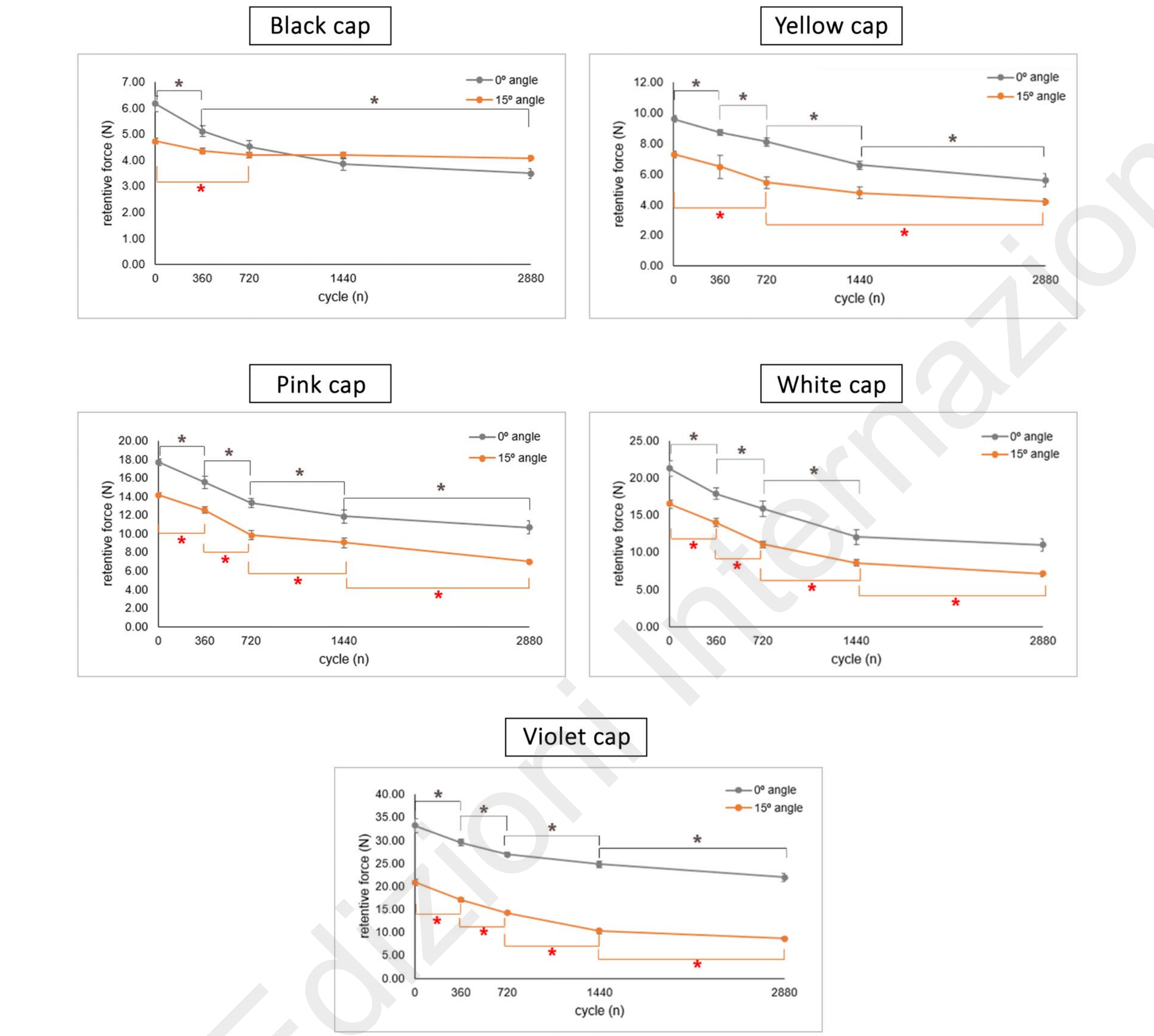

Figure 6
Significant differences of mean retentive force of each color coded retentive caps under cyclic dislodgement. (**P*-values were calculated at significant < 0.05).

torque ($P < 0.05$). The removal torque of different OT-Equator color-coded retentive caps in 0° and 15° angle at the end of 2,880 dislodging cycles are shown in Table 4. There were no statistically significant differences between 0° and 15° angle groups ($P > 0.05$). The removal torques within each color-coded retentive caps in 15° angle groups were lower than those of the 0° angle groups except for the pink cap (Figure 7). There was no complete screw loosening found after 2,880 cycles. From SEM inspection, there were neither damage nor shape alteration found compared to the new attachment screw (Figure 8).

Discussion

This in-vitro study evaluated the change of retentive force and removal torque of OT-Equator

Table 2 - Percentage of attachment retention loss compared to initial retention.

Angulation	Cycle (n)	Black (%)	Yellow (%)	Pink (%)	White (%)	Violet (%)
0°	360	-17.01	-9.05	-12.44	-16.07	-11.14
	720	-26.48	-15.73	-24.83	-25.65	-18.97
	1440	-37.58	-31.56	-32.91	-43.43	-25.40
	2880	-43.32	-41.79	-39.69	-48.26	-33.97
15°	360	-7.76	-11.27	-11.47	-14.94	-18.04
	720	-11.13	-25.37	-30.41	-32.84	-31.79
	1440	-11.14	-34.66	-36.30	-47.97	-50.97
	2880	-13.92	-42.37	-50.82	-57.18	-58.47

Table 3 - Removal torque of different OT-Equator color-coded retentive caps in 0° and 15° angle at 2,880 dislodging cycles compared to initial insertion torque.

OT-Equator retentive cap	Removal torque (Ncm)	*P*-value comparing with initial insertion torque	Removal torque (Ncm)	*P*-value comparing with initial insertion torque
	Mean ± SD		Mean ± SD	
	0° angle		15° angle	
Black	21.63 ± 2.72	0.0123*	20.71 ± 2.00	0.0007*
Yellow	21.7 ± 2.25	0.0056*	20.54 ± 1.79	0.0003*
Pink	19.83 ± 1.46	0.0000*	20.57 ± 1.08	0.0000*
White	20.37 ± 1.53	0.0001*	20.06 ± 1.77	0.0001*
Violet	20.97 ± 1.25	0.0000*	20.02 ± 2.18	0.0005*

* Statistically significant differences ($P < 0.05$).

Table 4 - The removal torque of different OT-Equator color-coded retentive caps in 0° and 15° angle at 2,880 dislodging cycles.

OT-Equator retentive cap	Removal torque (Ncm)	t-test	
	Mean ± SD		
	0° angle	15° angle	*P*-value
Black	21.63 ± 2.72	20.71 ± 2.00	0.559
Yellow	21.7 ± 2.25	20.54 ± 1.79	0.393
Pink	19.83 ± 1.46	20.57 ± 1.08	0.390
White	20.37 ± 1.53	20.06 ± 1.77	0.775
Violet	20.97 ± 1.25	20.02 ± 2.18	0.423

* Statistically significant differences ($P < 0.05$).

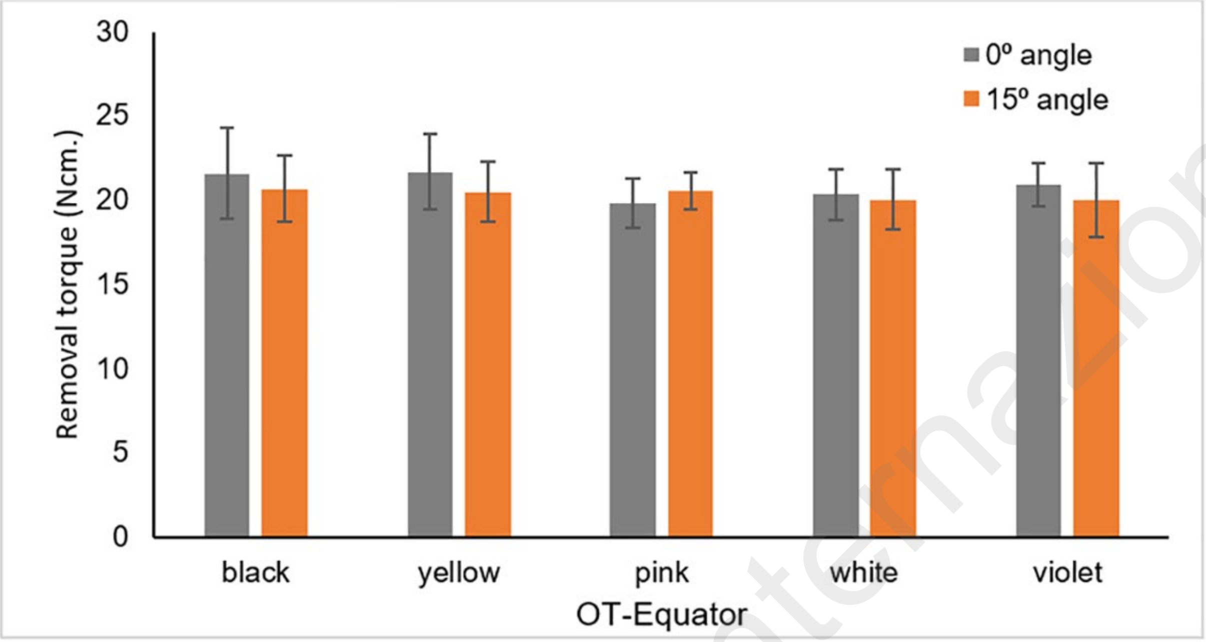

Figure 7
The removal torque of different OT-Equator color-coded retentive caps in different angulation after 2,880 cyclic dislodgement.

attachments in different angulations under cyclic dislodgement. The results of this study revealed that the increase in cyclic dislodgement significantly reduced the retentive force of OT- Equa-

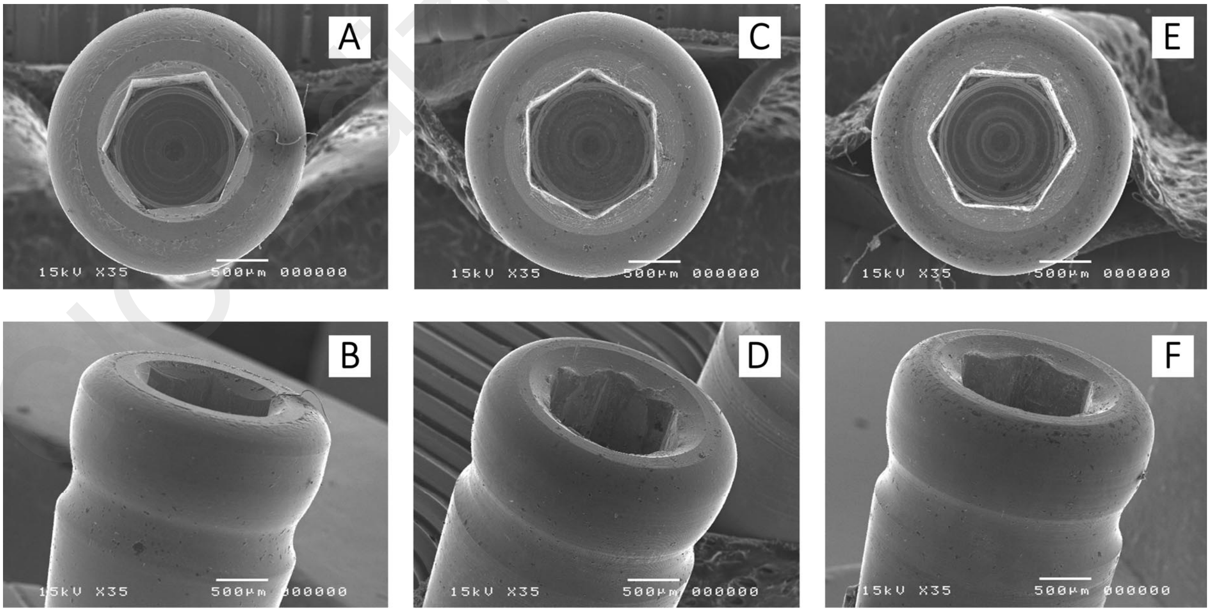

Figure 8
SEM images of the patrix surface (attachment abutment) after 2,880 cyclic dislodgement; abutment before test (A, B), abutment after test at 0° angle (C, D), abutment after test at 15° angle (E, F).

tor retentive caps in 15° than 0° angle, except for the black cap. The removal force also decreased at the final dislodging cycle. However, there were no statistically significant differences between removal torques of attachment components on mini implant in different angulations.

The implant retained or supported overdenture should have adequate retentive capacity to enhance the retention of the prosthesis (17). Previous studies revealed that implant angulation and attachment component wear influenced the change in retentive force during long term wearing period (25-27, 30-34). In vitro studies investigated the change of retentive capacity after simulated insertion-removal usage with cyclic dislodgement (25-28, 30-34). In this study, the cycles of 360, 720, 1,440 and 2,880 were used to simulate in-vivo function of OT-Equator in 3 months, 6 months, 1 year and 2 years respectively which were based on 4 removal-insertions per day. The results of this study demonstrated significant differences in baseline retention between nylon retentive components of which the violet cap was the most retentive, followed by the white, the pink, the yellow and finally the black cap. These weight color-code retentive caps indicated different levels of retention which varied from 6.16 ± 0.44 N to 33.24 ± 1.52 N. The relation of different color coded caps in the present study were in accordance with the investigations of other different attachment systems such as Locator (32, 33, 35). However, the retentive forces at the baseline of all groups were found higher than those of the manufacturer. Other previous studies have evaluated the retention capacity of OT-Equator attachment systems at the baseline. As for the pink cap at an angulation of 0°, Tomás et al. (28) obtained the initial retention value of 16.36 ± 2.94 N, which is similar to our study at 17.71 ± 0.38 N. However, Marin et al. (25) demonstrated greater baseline retention of pink female component at 51.81 ± 2.64 N which was in discordance with our study due to different designs of experimental models consisting of a pair attachment. In addition, some studies found that the relation between the initial retention force and color-coded retentive caps were independent (27, 34). These discrepancies might be caused by manufacturing process, different design and position of attachment systems (32).

After cyclic dislodgement, gradually progressive loss of retention was exhibited with similar pattern in all retentive caps of both 0° and 15 °of angulation. After 2,880 insertion-removal cycles, all groups exhibited loss of retention corresponding with retentive level of different color coded retentive caps. Within each color-coded retentive cap of each angulation, there were statistically significant differences of mean retentive force values overtime ($P < 0.05$). The black cap group exhibited the lowest retention with no significant differences of retentive force overtime between 0° and 15° angle groups ($P > 0.05$). This finding can be explained by the fact that the black processing cap is recommended to be removed and replaced by other color-coded retentive caps before function due to its inadequate retention. Previous studies reported that the increase of insertion/removal cycle had significant effects on retentive force reduction of various attachments which the experiments were on parallel implants or at right angle to occlusal plane. Marin et al. (25) found that pair implants OT-Equator with pink retentive caps exhibited 14.08% loss retentive force after 3,000 insertion/removal cycle at 0° of angulation. The present study showed 39% loss of retention at 2,880 final cycles on single attachment whereas Tomás et al. (28) presented 8.07% loss of retention at 3,000 cycles. The Authors also compared the retentive force of pink retentive cap between Locator and OT-Equator. They found that both systems showed similar characteristic at the baseline, however, OT-Equator (30.26%) obtained significant lower retention than those of Locator (49.76%) after 14,600 cycle. Another study, however, revealed that retentive force reduction of Locator was considerably up to 78.6% of baseline retention after 15,000 cycles. The different color coded retentive components of Locator were also reported that they might not necessarily provide significantly different retention (27). Regardless of different attachment systems and design of experimental studies, the retentive force reduction has been reported discrepancies range of retentive values. These results cannot be directly compared. However, all studies showed similar tendency of a decrease in retention after insertion-removal cycles.

In clinical situation, it can be complicated to place implants parallel to each other according to insufficient bone quality or anatomical limitations as well as patient affordability of prostheses. According to the manufacture, OT-Equator is designed with an abutment to be placed at angulation of between 0° and 15°. The present study investigated differences in retentive force values between different angulations. The results revealed that the 15° angle group had a significant greater loss of retentive force than the 0° angle group except for the black cap. Many studies have stated that an increasing implant angulation under cyclic dislodgement had negative effect on retention of implant overdenture which supported the finding in the present study (30, 31, 34). Al-Ghafli et al. (30) reported significant decrease in retention of Locator among 0°, 5°, 10°, 15° and 20° angle groups which 20° angle exhibited the lowest values after 15,000 cycles. Another study showed correspondingly significant decrease of retention at 0°, 10°, 20° angulation at 1,440 cycles, while vigorously loss of retention was found at 30°, 40° angulation after 720 cycles (31). The 20° angulation of Clix (Preat Corporation, CA, USA), Dalbo-Plus (Cendres+Métaux, Biel-Bienne, Switzerland) and Locator also revealed higher loss of retention when compared to 0° angle (34).

The main cause of a decrease in retention after frequent loading could be the wear induced-structural changes of attachment (17, 27). The higher angulation of inner part of attachment, the higher force needs of insertion-removal force. The consequent increase in friction force caused abrasion and deformity of nylon inserts of patrix attachment which was significantly detected in higher implant angulation (25, 27, 34). OT-Equator nylon components are made of polyamide which offers light weight, smooth surface, chemical resistance, dimensional stability and flexibility (25). However, the nylon components have a high sensitivity to wear during long term function due to several factors which consequently lead to decrease in retentive force (31). As a result, the change of morphology and wear of attachment component due to nonparallel implant and recurrent loading overtime could lead to loss of retention. Different studies revealed retention to stabilize mandibular overdenture ranging from 5-7 N from Pigozzo (5) and Besimo (36). In contrast, Setz (37) required 20 N of minimal retention for two-implant mandibular overdenture. As for loss of retention after long term usage, the proper period of time to replace the attachments of implant retained or supported overdenture is not well defined (30). According to the results of this study, it can be assumed that OT-Equator retentive with 0° angle until 2-year simulating insertion-removal function can still provide adequate retention with a retentive force ranging from 5.60 ± 0.44 N to 33.24 ± 1.52 N. However, the yellow cap with angulation of 15° after 1,440 cycles obtained too low retention to retain overdenture with a retentive value of 4.77 ± 0.38 N. This was lower than that referenced by different Authors (5, 36). Therefore, the nonparallel attachment may require 1 year of maintenance and be replaced by a new retentive cap.

The removal torque is the amount of rotational force used to loosen the screw which is used to analyze the remaining torque after mechanical loading compared to preload (38, 39). The removal torque investigations of overdenture attachment are currently lacking in dental research. There was a study of Kobayashi et al.

(26) who evaluated the effect of cyclic dislodgement on retention and removal torque of Locator on normal implant diameter (Straumann Regular Neck 4.1mm) after 14,600 insertion/removal cycles. The study found a significant decrease of both removal torque of Locator with 0° angle (29.5 ± 3.30 Ncm) and those with 12°angle (29.5 ± 4.17 Ncm) in comparison to initial insertion torque (35 Ncm). The results of both angulations exhibited similar values after final cyclic dislodgement. These findings are in accordance with the present study on mini implants (PW Plus 3.0mm) of which the removal torque of all attachment abutments were statistically significant lower at the final cyclic dislodgement than those at the initial (25 Ncm). Winkler et al. (40) explained that 2% to 10% of initial preload was lost as a result of settling effect. Accordingly, the removal torque exhibited less than the torque initially used to place the screw. Moreover, the external joint separating force such as non-axial load and insertion-removal force might allow separation of the joint and lead in screw loosening (40). However, from the results of the present study, no statistically significant differences were found in removal torques between 0° (ranged from 19.83 ± 1.53 to 21.70 ± 2.25 Ncm) and 15° of angulation (ranged from 20.02 ± 2.18 to 20.71 ± 2.00 Ncm) after 2,880 cycles. Therefore, there was no significant influence of the implant-angulation on removal torque after 2,880 cycles, even if the attachment was inserted on mini implant. This finding could be explained by damage of the attachment due to mechanical loading was limited on retentive components which is in accordance to previous studies (26, 34, 41). Aroso et al. (34) did not detect any visible deformation in the surface of Locator metal abutment even in different angulation but confirmed the wear in the internal part of white, pink and blue retentive components after 5,400 cycles. In addition, another *in vivo* study demonstrated significant wear of the nylon insert of Locator attachment under micro-computed tomography after 1 year of clinical wearing. There was no significant wear pattern on the abutments, despite the minimal scratch on its external surface under SEM evaluation (41). However, three-dimensional movement around the implant axis during mastication, cleaning agents, parafunctional habit and water absorption could be other important factors influencing the wear discrepancies of attachment systems (30, 34).

Within the limit of the study, it was concluded that greater cyclic dislodgement and increasing of implant angulation significantly affected retentive force of OT-Equator attachments. The value of retentive force of OT-Equator in simulating 2 year of denture insertion-removal is acceptable to retain mini implant overdenture. The removal torque after 2,880 cycles decreased when compared to insertion torque, however the implant angulation did not seem to have significant influence on removal torque. The low-profile OT-Equator can be used on mini implant to retain overdenture. Nevertheless, it should be noted that Nylon inserts with increased implant angulation required regularly follow up to replace them each year and screw re-tightening should be considered. Further *in vivo* studies are necessary to investigate the retentive behavior and its long term clinical relevance.

Conclusions

Within the limitations of this *in vitro* study, it can be concluded that:

1. Greater cyclic dislodgement and increasing of implant angulation significantly affected on retentive force of OT-Equator attachment.
2. The reduction of removal torque after 2,880 cycles was found, however the implant angulation did not seem to have significant influence on removal torque.
3. The value of retentive force of OT-Equator in simulating 2 year of denture insertion-re-

moval is acceptable to retain mini implant overdenture.
4. Nylon inserts with increase implant angulation required regularly follow up to replace them each year and screw re-tightening on attachment should be considered.

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References

1. Fitzpatrick B. Standard of care for the edentulous mandible: A systematic review. J Prosthet Dent. 2006;95(1):71-8.
2. Critchlow SB, Eliss JS. Prognostic indicators for conventional complete denture therapy: a review of the literature. J Dent. 2010;38(1):2-9.
3. Fueki K, Kimoto K, Ogawa T, Garrett NR. Effect of implant-supported or retained dentures on masticatory performance: a systematic review. J Prosthet Dent. 2007;98(6):470-7.
4. Siadat H, Alikhasi M, Mirfazaelian A, Geramipanah F, Zaery F. Patient satisfaction with implant-retained mandibular overdentures: a retrospective study. Clin Implant Dent Relat Res. 2008;10(2):93-8.
5. Pigozzo MN, Mesquita MF, Henriques GE, Vaz LG. The service life of implant-retained overdenture attachment systems. J Prosthet Dent. 2009;102(2):74-80.
6. Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, et al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. Int J Oral Maxillofac Implants. 2002;17(4):601-2.
7. Thomason JM, Kelly SA, Bendkowski A, Ellis JS. Two implant retained overdentures - A review of the literature supporting the McGill and York consensus statements. J Dent. 2012;40(1):22-34.
8. Sivaramakrishnan G, Sridharan K. Comparison of patient satisfaction with mini-implant versus standard diameter implant overdentures: a systematic review and meta-analysis of randomized controlled trials. Int J Implant Dent. 2017;3(1):29.
9. Laney WR. Glossary of Oral and Maxillofacial Implants. Int J Oral Maxillofac Implants. Chicago:Quintessence Publishing Co;2007, p.40, 102, 113, 133.
10. Flanagan D, Mascolo A. The mini dental implant in fixed and removable prosthetics: a review. J Oral Implantol. 2011;37 Spec No:123-32.
11. Jeong S-M, Choi B-H, Li J, Kim H-S, Ko C-Y, Jung J-H, et al. Flapless implant surgery: an experimental study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104(1):24-8.
12. Ahn M-R, An K-M, Choi J-H, Sohn D-S. Immediate loading with mini dental implants in the fully edentulous mandible. Implant Dent. 2004;13(4):367-72.
13. Bidra AS, Almas K. Mini implants for definitive prosthodontic treatment: a systematic review. J Prosthet Dent. 2013;109(3):156-64.
14. Elsyad M, Gebreel A, Fouad M, Elshoukouki A. The clinical and radiographic outcome of immediately loaded mini implants supporting a mandibular overdenture. A 3 year prospective study. J Oral Rehabil. 2011;38(11):827-34.
15. Aunmeungtong W, Kumchai T, Strietzel FP, Reichart PA, Khongkhunthian P. Comparative Clinical Study of Conventional Dental Implants and Mini Dental Implants for Mandibular Overdentures: A Randomized Clinical Trial. Clin Oral Implants Res. 2016;19(2):328-340.
16. Tomasi C, Idmyr BO, Wennström JL. Patient satisfaction with mini-implant stabilised full dentures. A 1-year prospective study. J Oral Rehabil. 2013;40(7):526-34.
17. Alsabeeha NH, Payne AG, Swain MV. Attachment systems for mandibular two-implant overdentures: a review of in vitro investigations on retention and wear features. Int J Prosthodont. 2009;22(5):429-40.
18. Daou EE. Stud attachments for the mandibular implant-retained overdentures: Prosthetic complications. A literature review. Saudi Dent J. 2013;25(2):53-60.
19. Cakarer S, Can T, Yaltirik M, Keskin C. Complications associated with the ball, bar and Locator attachments for implant-supported overdentures. Med Oral Patol Oral Cir Bucal. 2011;16(7):e953-e9.
20. Kleis WK, Kämmerer PW, Hartmann S, Al-Nawas B, Wagner W. A comparison of three different attachment systems for mandibular two-implant overdentures: one-year report. Clin Implant Dent Relat Res. 2010; 12(3):209-18.

21. Elsyad MA. Patient satisfaction and prosthetic aspects with mini-implants retained mandibular overdentures. A 5-year prospective study. Clin Oral Implants Res. 2016;27(7):926-33.
22. Schwindling FS, Schwindling FP. Mini dental implants retaining mandibular overdentures: A dental practice-based retrospective analysis. J Prosthodont Res. 2016;60(3):193-8.
23. El-Anwar MI, Mohammed MS. Comparison between two low profile attachments for implant mandibular overdentures. J Gen Eng Biotech. 2014;12(1):45-53.
24. Ammar NA, El-Khodary NM, Abdelhamid AM. Clinical Evaluation of the Implant Retained Overdenture with OT-Equator Attachments. Int J Sci Res. 2016; 5(9):643-647.
25. Marin D, Leite A, Junior N, Paleari A, Pero A, Compagnoni M. Retention Force and Wear Characteristics of three Attachment Systems after Dislodging Cycles. Br Dent J. 2018;29(6):576-82.
26. Kobayashi M, Srinivasan M, Ammann P, Perriard J, Ohkubo C, Müller F, et al. Effects of in vitro cyclic dislodging on retentive force and removal torque of three overdenture attachment systems. Clin Oral Implants Res. 2014;25(4):426-34.
27. Rutkunas V, Mizutani H, Takahashi H, Iwasaki N. Wear simulation effects on overdenture stud attachments. Dent Mater J. 2011;30(6):845-53.
28. Tomás MN, Barquero J, Estevan L, Escuder A, Otaolaurruchi EJ. In vitro retention capacity of two overdenture attachment systems: Locator® and Equator®. J Clin Exp Dent. 2018;10(7):e681-e686.
29. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. J Prosthet Dent. 2003;90(2):121-32.
30. Al-Ghafli SA, Michalakis KX, Hirayama H, Kang K. The in Vitro Effect of Different Implant Angulations and Cyclic Dislodgement on the Retentive Properties of an Overdenture Attachment System. J Prosthet Dent. 2009;102(3):140-7.
31. Teimoori H, Shayegh SS, Zavaree MA, Hakimaneh SM, Khodadad F, Shidfar S, Baghani MT. Effects of Excessive Implant Angulation on Retention of Two Types of Overdenture Attachments during Cyclic Loading. J Contemp Dent Pract. 2018;19(10):1221-1227.
32. Tehini G, Baba N, Majzoub Z, Nahas P, Berberi A, Rifai K. In Vitro Effect of Mastication on the Retention and Wear of Locator Attachments in a Flat Mandibular Ridge Model. J Prosthodont. 2018;28(2):e74-e751.
33. Evtimovska E, Masri R, F. Driscoll C, et al. The Change in Retentive Values of Locator Attachments and Hader Clips over Time. J Prosthodont. 2009;18 (6):479-83.
34. Aroso C, Silva AS, Ustrell R, Mendes JM, Braga AC, Berastegui E, Escuin T. Effect of abutment angulation in the retention and durability of three overdenture attachment systems: An in vitro study. J Adv Prosthodont. 2016;8(1):21-9.
35. Rabbani S, Juszczyk AS, Clark RK, Radford DR. Investigation of Retentive Force Reduction and Wear of the Locator Attachment System with Different Implant Angulations. Int J Oral Maxillofac Implants. 2015; 30(3):556-63.
36. Besimo C, Guarneri A. In vitro retention force changes of prefabricated attachments for overdentures. J Oral Rehabil. 2003;30(7):671-8.
37. Setz I, Lee SH, Engel E. Retention of prefabricated attachments for implant stabilized overdentures in the edentulous mandible: an in vitro study. J Prosthet Dent. 1998;80(3):323-9.
38. Katsuta Y, Watanabe F. Abutment screw loosening of endosseous dental implant body/abutment joint by cyclic torsional loading test at the initial stage. Dent Mater J. 2015;34(6):896-902.
39. Pintinha M, Camarini ET, Sábio S, Pereira JR. Effect of mechanical loading on the removal torque of different types of tapered connection abutments for dental implants. J Prosthet Dent. 2013;110(5):383-8.
40. Winkler S, Ring K, Ring JD, Boberick KG. Implant screw mechanics and the settling effect: overview. J Oral Implantol. 2003;29(5):242-5.
41. Jabbour Z, Fromentin O, Lassauzay C, Abi Nader S, Correa JA, Feine J, de Albuquerque Junior RF. Effect of Implant Angulation on Attachment Retention in Mandibular Two-Implant Overdentures: A Clinical Study. Clin Implant Dent Relat Res. 2014;16(4):565-71.

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