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RESEARCH

Evaluation of the effect of oral health care product on the reverse torque value of the titanium prosthetic screw of an implant-supported crown following cyclic loading

Sibi Kumar, Jaya Krishna Kumar S*, **Hariharan Ramakrishnan, Vallabh Mahadevan, Vidhya Jeyapalan and Azhagarasan N. S**

Department of Prosthodontics and Implantology, Ragas Dental College and Hospitals Chennai, India

***Correspondence:**
Jaya Krishna Kumar S,
jayakrishnakm@yahoo.co.in

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Purpose of the study: To comparatively evaluate *in vitro* the effect of oral health care product on the reverse torque value of the titanium prosthetic screw of an implant-supported crown following cyclic loading.
Materials and methods: Ten titanium screw-retained implant Co-Cr crowns without application of oral health care product (Group I) and ten titanium screw-retained implant Co-Cr crowns with the application of oral health care product (GC Tooth Mousse) (Group II) were connected to their respective analogs and prosthetic screws were torqued to 30 Ncm using a digital torque meter. Reverse Torque Values were measured before cycling loading and all the twenty samples were subjected to a cyclic loading simulating six months' duration of the function. Reverse Torque Values were subsequently measured postcyclic loading. The results were analyzed using the Paired 't' test and the Independent 't' test.
Results: The mean precyclic loading reverse torque values were 26.12 Ncm (Group I) and 26.57 Ncm (Group II) and the mean postcyclic loading reverse torque values were 22.49 Ncm (Group I) and 24.10 Ncm (Group II). There was no significant loss of preload for Group II test samples prior to cyclic loading compared to Group I test samples. Cyclic loading resulted in reduction of reverse torque values for both Group I and Group II test samples, indicating screw loosening. After cyclic loading, Group II test samples showed significantly higher detorque value than Group I test samples.
Conclusion: Cyclic loading resulted in screw loosening in both test groups. Screw loosening was found to be significantly less for Co-Cr prosthetic screw-retained implant crown with the application of GC Tooth Mousse than Co-Cr prosthetic screw-retained implant crown without application of GC Tooth Mousse.

Keywords: torque, implant-supported dental prosthesis, dental implant abutment design

Introduction

The predictable nature of osseointegration has prompted clinicians to treat partial and complete edentulism using dental implants with a considerable improvement in the patient's quality of life (1–3). Nevertheless, the high survival and success rates could be jeopardized by the complications arising from biological and mechanical issues (4–6).

There are basically two methods used to secure an implant-supported restoration, namely, screw retention and cement retention (7). Many practitioners are encouraged to use screw retention as it offers the ability to retrieve an implant prosthesis in the event of any complication. The screw access channel should be positioned in an area to optimize the final esthetic outcome of an implant-supported restoration. To mitigate situations arising from anesthetic screw access opening due to the malposition in implant placement, cement retention is mainly preferred by clinicians (7).

The main advantage of using screw-retained restorations is its predictability in retrieving the prosthesis in the event of mechanical or biological failure. A screw-retained implant-supported crown/abutment assembly can be directly attached to the implant through a prosthetic screw, resulting in a direct fixture connection (7) Abutment screw loosening is found to be the most frequent mechanical complication with restoration on dental implants. Stripping of screw heads is another potential technical complication with respect to screw-retained implant prosthesis. The abutment or the prosthetic screw is usually considered the feeble part of the prosthetic assembly. Possible sequelae related to this consequence are screw joint instability leading to marginal gap opening, microbial leakage, screw fracture, and prosthesis debonding (5).

The technical complications are usually because of the repeated process of tightening and loosening the screws, resulting in wear and physical alterations to the screw head and improper position of the screwdriver, and the application of excessive torque may also lead to screw head stripping (8–10).

A basic understanding of screw mechanics is essential in order to deliver patients with high-quality implant-supported screw-retained restoration (11).The clinician must be familiar with the implant prosthetics screw mechanics in order to keep the screw secured. A screw's main objective is to produce and sustain a compressive force between the joint members, clamping force. As the joint mating parts are compressed against each other, tension is developed within the screw. This tensile force is known as "preload" (12–15). Care should be exercised not to exceed the upper limit of the yield strength of the screw material. The longevity of the screw joint mainly depends on the stability of the clamping force (6, 15) as a very high clamping force should be generated to resist forces acting to separate the joint.

One important variable that determines the implant–abutment joint stability is the change that occurs between the contacting parts when the screw is tightened. The microroughness produced due to the presence of high and low points on the metal mating surfaces flattens slightly decreasing the space between them, which leads to a phenomenon known as the "Settling effect" (10, 11, 14), where the screw loses part of its preload, hence it has been strongly established that retightening of the implant-abutment or prosthetic screw after initial tightening and during follow-up is essential to lessen screw loosening (8, 9, 14, 16).

Factors affecting the preload are screw head and thread design, thread number, the composition of screw material, presence of fluid contaminants (6, 9, 13) and lubricants, torque delivery system, non-passive framework, poor occlusal morphology of the prosthesis, and parafunctional habits can also lead to screw loosening (3, 9).

Screw loosening or fracture is more common with prosthetic screws than with abutment screws. Screw separation is also more significant in single-unit implant restoration compared with multiple units mainly, mandibular molar crowns (5).

To counteract these problems, the manufacturer has recommended the use of coated abutment screws to prevent prosthesis debonding (10, 14). Coatings such as diamond-like carbon, nitride and gold have been shown to minimize screw loosening (13). Coating the abutment screw decreases the friction coefficient and increases the preload for given tightening torque. The implant–abutment/prosthetic connection is prone to contamination with several fluids mainly blood and saliva, commencing from the surgical procedure till the prosthetic phase. This contamination could affect the preload and subsequently increase the chances of screw loosening (5, 9, 11). Increased preload values have been demonstrated with the presence of saliva at the implant–abutment interface. A study performed by Duarte et al. (17) has reported contamination by fluoridated artificial saliva produced increased reverse torque value.

During routine home oral care hygiene procedures, there is a possibility of seepage of oral fluids, mainly saliva contaminated with various food debris, dentifrices, oral rinses (5, 18), etc., which have been found to modify the prosthetic screw mechanics. Some of these contaminants possess lubricating properties and are said to minimize screw loosening.

Several oral health care products have been developed to prevent demineralization of the enamel surface. GC Tooth Mousse is a unique product containing Amorphous Calcium Phosphate (ACP) and Casein PhosphoPeptide (CPP), which is obtained from milk casein (19). Several *in vitro* and *in vivo* studies have demonstrated that treatment with ACP-CPP improves increase in enamel remineralization. This product is also recommended for patients exhibiting high caries activity, hypersensitivity, and xerostomia.

Limited studies have evaluated coating materials on the implant prosthetic screws possessing lubricating property. Materials such as grease (20), cyanoacrylate-based compounds, and silicone gels (21) are used as screw fasteners and to prevent screw loosening from vibrations and are used in the field of mechanical engineering.

Studies utilizing Tooth Mousse as a lubricating agent for the prosthetic screw have not been .evaluated till now.

During mastication, occlusal loading may cause micromotion loosening, increase in the micro gap at the implant–abutment interface leading to microbial colonization (22) of the internal cavity of the implant, which can also lead to loss of preload. There is a possibility of screw loosening through occlusal loading when the force exceeds the preload of the screw.. Reverse Torque Value (8, 23) is a quantitative method to measure the resistance provided by the torqued prosthetic screw to loosening. It is the residual preload present in the screw after applying torque. Assessment of reverse torque value can be accomplished using a calibrated torque wrench, which can be either a manual type (1, 8, 11, 21) or a digital. The advantage of using

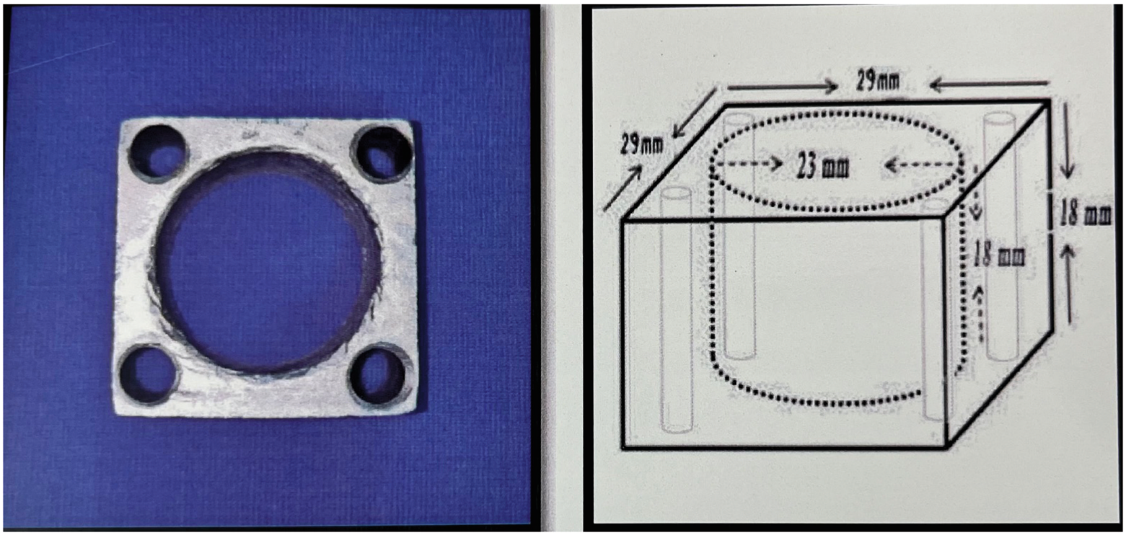

FIGURE 1 | Custom-made stainless steel mode and line diagram.

a digital torque meter is that it can produce accurate levels added with data storage and transfer facility.

Cyclic loading tests (1, 21, 24) have been adopted in several *in vitro* studies to mimic functional loading situations and their impact on the preload of the prosthetic screw. Cyclic loading evaluations are usually conducted either using axial and/or non-axial directional loads. Clinically, maxillary anterior teeth are usually subjected to off-axial loads and this is mainly related to the inclination of these teeth that is required for the esthetics and function leading to unavoidable oblique force transmission. Off axial loading is likely to generate more stresses than vertical loading and may be the reason contributing more stress concentration around the Bone–Implant interface, furthermore leading to micromotion in the screw joint assembly, screw loosening, and formation of the micro gap (1). *In vitro* studies employing maxillary anterior teeth have utilized non-axial loading forces delivered at angulation ranging between 30° and 45°. Studies comparing the influence of oral health care products on the prosthetic screw loosening before and after cyclic loading are very sparse. Studies have been conducted comparing different types of oral fluid contaminants, such as fluorides, chlorhexidine, and industrial lubricants on the screw loosening.

In light of the above, the aim of this *in vitro* study was to comparatively evaluate the effect of oral health care product on the reverse torque value of the titanium prosthetic screw of an implant-supported crown following cyclic loading. The null hypothesis for this study is that the presence of oral health care products will not have any effect on the reverse torque value of the titanium prosthetic screw.

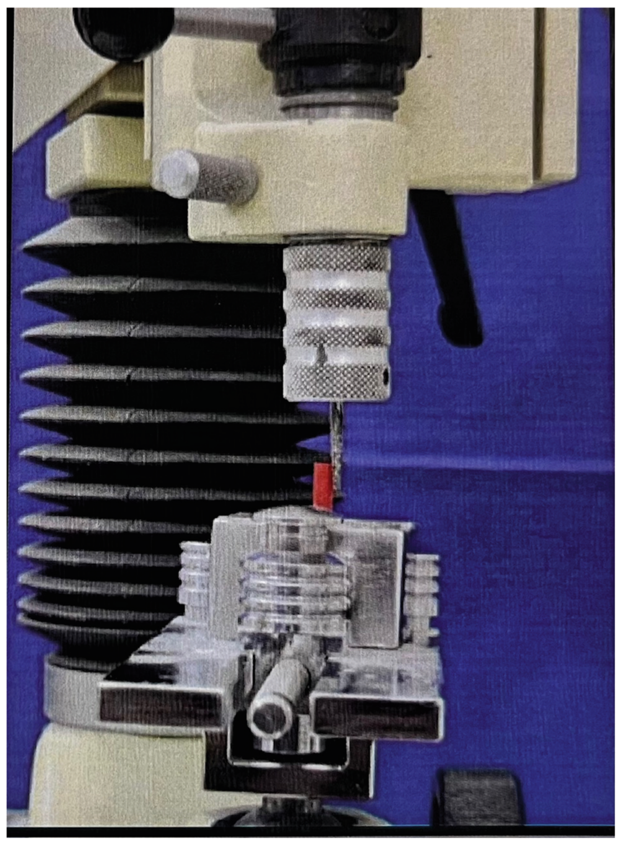

FIGURE 2 | Milling of abutment.

Materials and methods

A stainless-steel mold of dimensions 29 mm × 29 mm × 18 mm with a cylindrical mold space of diameter 23 mm and depth of 18 mm was custom-made (**Figure 1**) Four holes each with a diameter of 3 mm and a depth of 18 mm were drilled

FIGURE 3 | Group 1 test samples.

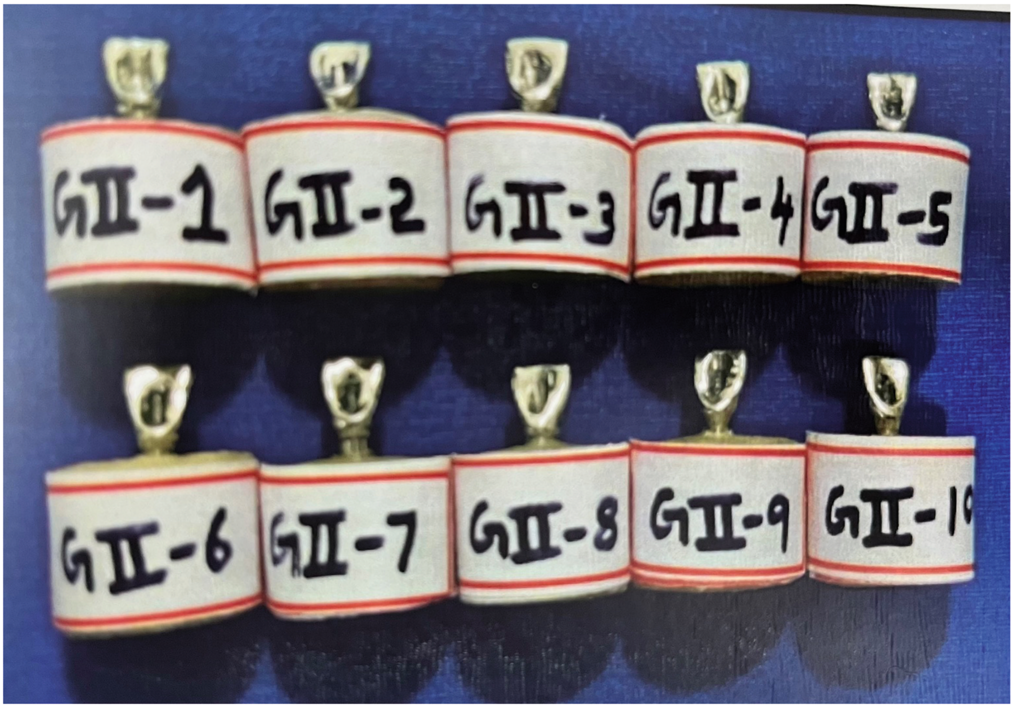

FIGURE 4 | Group 11 test samples.

at the four corners of the mold in order to stabilize it to the custom-made positioning jig using a bolt.

Twenty regular standard internal hex implant analogs (NORIS Dental Implants, Israel) were used. Each of the twenty analogs were randomly selected and connected to one randomly selected UCLA plastic abutment (NORIS Dental Implants, Israel) by hand torquing the titanium prosthetic screw with a hex driver (NORIS Dental Implants, Israel).

A custom-made stainless-steel mold was placed on the platform of a dental surveyor (Saeshin Precision Ind. Co., Korea), and using spirit level indicators (Jinhua Hengda tools, China) the surveying platform was made parallel to

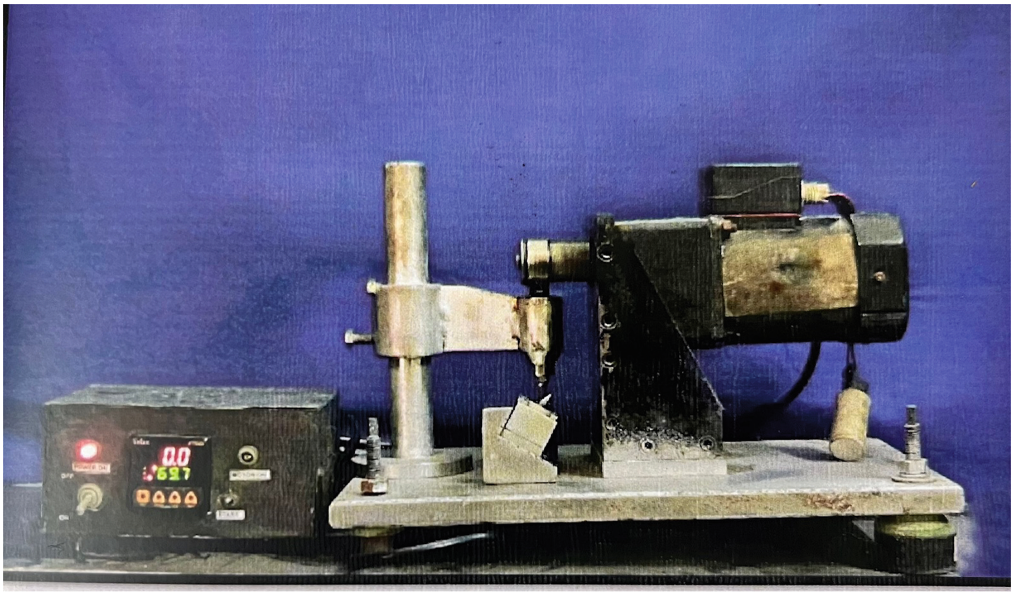

FIGURE 5 | Cyclic loading machine.

the floor. Then UCLA plastic abutment is connected to the implant analog and was attached to the surveying mandrel and positioned in the center of the stainless steel cyclindrical mold space , such that the analog was submerged completely in the same mold space except for the 1mm at the crest module.

Auto polymerizing clear acrylic resin (Cold Cure, DPI, India) was mixed as per the manufacturer's recommendations and poured into the mold space, and then allowed to polymerize. This procedure was repeated to obtain 20 acrylic blocks. After polymerization of the acrylic resin, the UCLA plastic abutment was removed from the analog by detorquing of the titanium prosthetic screw using the hex driver. The positioned implant analog level was then visually verified.

One UCLA plastic abutment (NORIS Dental Implants, Israel) was then connected to the implant analog by hand torquing the titanium prosthetic screw using the hex driver. The connected UCLA plastic abutment was then milled using a dental surveyor attached with a milling unit (Bredent GmbH & Co., Germany) (**Figure 2**). In this manner, the UCLA plastic abutment was milled. The milled UCLA plastic abutment was then unscrewed and removed from the implant analog. The same protocol was followed to obtain twenty milled UCLA plastic abutments of uniform dimensions which were ready for casting and the milled UCLA plastic abutment was separated from the stainless-steel mold.

Wax-up was done on the milled UCLA plastic abutment with inlay casting (GC Corporation, Tokyo, Japan) to obtain a single unit crown resembling a maxillary central incisor. The cingulum area was over contoured to create a flat surface at a 30° inclination to the long axis of the tooth. After the wax pattern fabrication, the prosthetic screw access channel was relieved to facilitate the placement of the prosthetic screw. A screw access hole was placed in the middle third region of the palatal side of the crown. A total of twenty standardized wax patterns were obtained in this manner. Each wax pattern was sprued with a preformed wax sprue (REF 40085, Bego, Germany) of 2.5 mm diameter. The wax sprue was attached to the incisal edge of the pattern and a reservoir was placed 1.5 mm away from the pattern. The pattern was directly sprued to the crucible former using a ringless casting system (Sili Ring, Delta Labs, Chennai, India). All the 20 wax patterns were sprued individually in a similar manner.

All the 20 wax patterns were invested individually using graphite-free, phosphate-bonded investment material (Bella sun, Bego, Germany) suitable for Co-Cr alloy casting. A 6 mm distance was provided between the pattern and the top of the ring. All patterns were sprayed with surfactant spray (Aurofilm, Bego, Germany) to aid in better wetting of the investment material. Following the manufacturer's recommendation, 160 gm of the phosphate-bonded investment was mixed with 38 ml of investment liquid, which was prepared by mixing 30 ml of colloidal silica (Begosol, Bego, Germany) and 8 ml of distilled water in a ratio of 3:1. The investment powder was first hand mixed with a spatula until the entire material was wetted thoroughly followed by vacuum mixing for 30 s using a vacuum power mixer (Whipmix, Kentucky, U.S.A.). The entire pattern was painted with a thin layer of investment using a small paintbrush. The silicone ring was positioned on the crucible former and the remainder of investment was poured and vibrated slowly into the ring. All the 20 wax patterns were invested in a similar manner. The invested patterns were allowed to bench set for 20 min, and the silicone ring was removed. The invested patterns were labeled for future identification.

All the invested patterns were allowed to completely set for 1 h and then placed in a burnout furnace (Technico, Technico laboratory products Pvt. Ltd., Chennai, India) for wax burnout. Investments mold for a period of three hours. During the first hour, the temperature was raised from room temperature to 380°C; in the second hour, the temperature was raised to 900°C and during the last hour the temperature was sustained at 900°C to accomplish complete burnout of the pattern without any residue. The investment mold was initially placed in the furnace such that the crucible end was in contact with the floor of the furnace for the escape of molten material. The investment mold was reversed later near the end of the burnout cycle with the sprue hole facing upward to enable the escape of the entrapped gasses and also to allow oxygen contact to ensure complete burnout of the wax pattern. The same procedure was followed for the burnout of all twenty patterns.

Casting was accomplished individually with Co-Cr alloy (Wironit, Bego, Germany) melted in an induction casting machine (Fornax, Bego, Germany). The casting procedure was performed quickly to prevent heat loss resulting in thermal contraction of the mold. The Crucible containing Co-Cr alloy was heated to 1300°C following the manufacturer's recommendation for melting the alloy ingot and the crucible was released. The centrifugal force ensured the complete flow of the molten metal into the mold space. The same procedure was followed for casting all the twenty Co-Cr crowns.

The hot casting mold was allowed to cool to room temperature. A knife was used to trim the investment at the bottom end of the ring. It was then broken apart and the remaining investment was slowly removed. The adherent investment was removed from the casting by air abrasion using 110μm alumina (Korox, Chennai, India) at 80 psi pressure in a sandblasting machine (Delta Labs, Chennai, India). The sprue was cut using a 0.7 mm thin carborundum separating disk (Dentorium, New York, US). The casting was inspected under magnification for casting defects. Casting with irregularities in the internal margin, distorted surfaces were discarded. External surfaces were relieved of all nodules with a round carbide bur. All the 20 screw-retained Co-Cr cast crowns were trimmed using metal trimming burs (Edenta, Switzerland) and polished using silicon rubber wheels (Dentsply, Germany). Twenty finished screw-retained Co-Cr cast crowns with palatal screw access for each implant analog assembly were obtained.

Each of the screw-retained Co-Cr crowns were randomly selected and connected to its respective analog by hand torquing the titanium prosthetic screw with a hex driver. Each crown was visually checked for proper seating and marginal accuracy on its respective analog.

Using an applicator tip, GC Tooth Mousse (GC Corporation, Tokyo, Japan) material was coated along the entire surface of the 10 titanium prosthetic screws, and subsequently, the crowns were torqued to their respective implant analog.

A total of 20 implant-supported Co-Cr screw-retained crowns were fabricated for this *in vitro* study. Group I test samples were connected to their respective analog without the application of GC Tooth Mousse material onto the implant prosthetic screw ($n = 10$). Group II test samples were connected to their respective analog with the application of GC Tooth Mousse material onto the implant prosthetic screw ($n = 10$).

Following the initial manual tightening of the implant-supported screw-retained crowns to their respective Group I and Group II analogs (**Figures 3**, **4**), a digital torque meter was utilized to torque the screws to 30 Ncm of all the test samples.

The reverse torque value of each of the Group I and Group II test samples was recorded and noted. The hex driver (NORIS Dental Implants, Israel) was secured to the digital torque meter. The torque gauge was held firm, carefully oriented in the long axis of the implant analog with the driver seated in the screw head and rotated clockwise until the titanium prosthetic screw was tightened to 30 Ncm. A ten-minute settling time was allowed, following which it was retightened to 30 Ncm to minimize embedment relaxation between the mating threads and to achieve the optimal "preload." This procedure was repeated for all ten samples. After a waiting period of five minutes, the Reverse Torque Value (RTV) for each of the Group I test samples was measured individually using the digital torque meter (Eclatorq-1/4" model SP-2 BN). The torque required to loosen the titanium prosthetic screw was the quantum of preload remaining in the screw joint as against the tightening torque applied. This was designated as the precyclic loading Reverse Torque Value (preRTV1) for that test sample. Similarly for the Group II test samples, the Reverse Torque Values were measured and designated as the precyclic loading Reverse Torque Values (preRTV2). The Reverse Torque Value for each sample was displayed on the LCD screen of the digital torque meter (Eclatorq-1/4" model SP-2 BN) and was saved in its memory. The Precyclic loading reverse torque values of both Groups I and II test samples were recorded and tabulated separately.

Subsequent to the preRTV1 measurements, the titanium prosthetic screws of all ten Group I test samples ($n = 10$) were torqued to 30 Ncm and then retorqued after allowing a settling period of 10 min as described previously to ensure optimal preload before cyclic loading. The same procedure was followed for all ten test samples of Group II ($n = 10$). And screw access channel was plugged with Teflon tape (Badsha Thread sealing tape, Hussaini sales corporation, India) and then a layer of dentin bonding agent (Ivoclar Vivadent, Amherst, New York, United States) was applied using the applicator tip (DENMAX Micro applicators, The

Dental Professionals, India) and it was light-cured for 20 s using the LED light cure unit (Ivoclar Vivadent, Amherst, NY, United States) and the screw access was restored using a bulk-fill composite resin (Anabond Stedman pharma, India) and it is light-cured using the LED light cure unit (Ivoclar Vivadent, Amherst, New York, United States) for 20–30 s.

Cyclic loading was performed for all twenty test samples individually, with a custom-made cyclic loading machine (Lokesh Industries, Chennai) to simulate oral loading conditions. The test sample with the screw-retained cast restoration was placed in a custom-made positioning jig (Lokesh Industries, Chennai), which positioned and secured the sample at a 30° angle to the floor to simulate the direction of forces at the maxillary anterior region. This jig with the test sample was attached to the cyclic loading machine (**Figure 5**). The stylus of the cyclic loading machine was placed on the flattened cingulum portion of the cast Co-Cr central incisor crown. The test sample was subjected to cyclic loading. A sinusoidal waveform at 1.25 Hz for load up to 109 N (approximately) simulating human masticatory frequency and loads was applied. This cycle was continued for 42 h (2,520 mins with a break of 2 h, every 21 h) simulating 1,89,000 cycles, which was approximately 6 months of function. The cyclic loading was performed in a dry environment. This procedure was repeated for all the twenty test samples.

After the completion of the cyclic loading, the respective test sample was removed from the custom-made cyclic loading machine. The test sample was subjected to visual and tactile inspection for any deformation, or abutment rotation, or loosening. The Reverse Torque Value after cyclic loading for each of the Group I and Group II test samples was measured with the digital torque meter similar to that described before and recorded as the postcyclic loading Reverse Torque Values. The postcyclic loading Reverse Torque Values of Group I and Group II samples were designated as postRTV1 and postRTV2, respectively. The reverse torque difference (RTD) for each test group was then calculated individually by finding the difference between the respective postcyclic loading reverse torque value and precyclic loading Reverse Torque Value of each test sample of that test group [RTD = postRTV (−) preRTV] The mean Reverse Torque Difference (RTD) for Group I and Group II test samples were labeled as RTD1 and RTD2, respectively. The data thus obtained were subjected to statistical analysis.

The data obtained were tabulated using the Microsoft Excel (Microsoft, USA) and SPSS (SPSS for Windows 10.0.5, SPSS Software Corp., Munich, Germany) software. The paired "*t*" test was used to compare the mean pre- and postRTV within both test groups. The independent "*t*" test was used to compare the respective mean pre- and postcyclic loading reverse torque values and the respective mean reverse torque difference between the two test groups.

Results

The mean precyclic loading Reverse Torque Value for Group I test samples was 26.12 Ncm and for group II test samples was 26.57 Ncm. There was a considerable reduction in preload from the applied tightening torque of 30 Ncm for both the test groups. This loss in preload was found to be within the limits as evaluated in literature for loss of preload up to 20 percent for titanium prosthetic screws. The mean postcyclic loading Reverse Torque Value for Group I test samples was 22.49 Ncm and for group II test samples was 24.10 Ncm. The mean reverse torque difference for Group I test samples was found to be −3.63 Ncm and for Group II was −2.47 Ncm. In comparison, differences between respective pre-and postcyclic loading Reverse Torque Values for both Group I and Group II were found to be statistically insignificant (P value < 0.05).

On comparison of the mean precyclic loading Reverse Torque Value of Group I with that of Group II, no statistically significant difference was found. This can be attributed to the fact that both the test groups, irrespective of the surface coating of prosthetic screws, were titanium screws from the same manufacturer. On comparison of the mean postcyclic loading Reverse Torque Value of Group I with that of Group II, a statistically significant difference was found between the two groups. (P value < 0.05). On analysis using the Paired 't' test, it was found that the mean postcyclic loading Reverse Torque Value of Group I test samples (postRTV1) was less than the mean precyclic loading reverse torque value (preRTV1) and this was found to be insignificant (P value < 0.05). On analysis using the Paired 't' test, the mean postcyclic loading Reverse Torque Value of Group II test samples (postRTV2) was less than the mean precyclic loading reverse torque value (preRTV2) and this was found to be insignificant (P value < 0.05). On analysis using the Independent 't' test to compare the respective mean precyclic loading Reverse Torque Values of Group I and II test samples, the mean precyclic loading Reverse Torque Value of Group I test samples was less than that of Group II test samples and this was found to be insignificant (P value < 0.05). On analysis using the Independent 't' test to compare the respective mean Reverse Torque Difference of Group I and II test samples, the mean Reverse Torque Difference of Group II test sample was less than that of Group I test sample and this was found to be significant (P value < 0.05), (**Tables 1–11**).

Discussion

Advancements in dental biomaterials and the technological surge have seen rapid and remarkable progress in implant dentistry in the treatment of partially and completely edentulous patients (2, 3) Besides their beneficial nature, they are not without the risk of biological, mechanical, and esthetic complications (4, 6, 14).

TABLE 1 | Basic and mean precyclic loading Reverse Torque Values (preRTV1) of Group I test samples (Co-Cr screw-retained implant crown without application of oral health care product).

Sample No.	PreRTV1(Ncm)
GI 1	26.43
GI 2	26.01
GI 3	26.55
GI 4	25.97
GI 5	25.83
GI 6	26.85
GI 7	26.42
GI 8	26.23
GI 9	25.07
GI 10	25.87
Mean/S. D	26.123/ ± 0.494

TABLE 2 | Basic and mean postcyclic loading Reverse Torque Values (postRTV1) of Group I test samples (Co-Cr screw-retained implant crown without application of oral health care product).

Sample No.	PostRTV1(Ncm)
GI 1	22.12
GI 2	23.57
GI 3	22.81
GI 4	21.17
GI 5	23.47
GI 6	22.03
GI 7	23.69
GI 8	22.41
GI 9	21.89
GI 10	21.75
Mean/S. D	22.491/ ± 0.8611

TABLE 3 | Basic and mean Reverse Torque Differences (RTD1) of Group I test samples (Co-Cr screw-retained implant crown without application of oral health care product.

Sample no.	PreRTV1 (Ncm)	PostRTV1 (Ncm)	PostRTV1(-) PreRTV1 = RTD1 (Ncm)
GI 1	26.43	22.12	−4.31
GI 2	26.01	23.57	−2.44
GI 3	26.55	22.81	−3.74
GI 4	25.97	21.17	−4.80
GI 5	25.83	23.47	−2.36
GI 6	26.85	22.03	−4.82
GI 7	26.42	23.69	−2.73
GI 8	26.23	22.41	−3.82
GI 9	25.07	21.89	−3.18
GI 10	25.87	21.75	−4.12
Mean/S.D	26.123/ ± 0.494	22.491/± 0.861	−3.632/ ± 0.918

TABLE 4 | Basic and mean precyclic loading Reverse Torque Values (preRTV2) of Group II test samples (Co-Cr screw-retained implant crown with the application of oral health care product) (GC Tooth Mousse).

GII 1	26.27
GII 2	27.11
GII 3	25.42
GII 4	26.28
GII 5	26.57
GII 6	27.07
GII 7	27.01
GII 8	26.89
GII 9	27.03
GII 1O	26.11
Mean/S.D	26.576/ ± 0.553

The excessive force during centric and eccentric movements generates more stress on the implant superstructure, which is more prone to mechanical complications mainly porcelain chipping, screw loosening, or fracture (14). This is mainly related to the biomechanical difference between teeth and implants, where implants lack periodontal ligament.

Implant-supported restorations can be retained by screws or cement with each one having its own merits and demerits. Cement-retained prostheses are easy to fabricate, with a passive restoration and superior esthetics, but the main drawback of cement-retained restoration is its retrievability in the event of any complications (7).

Screw-retained restoration offers the advantage of retrievability of the prosthesis during review appointments and\or remaking of the restoration. Benefits of screw-retained restoration include ease of prosthesis repair and reducing the risk of peri-implantitis.

There are two kinds of implant abutment connections, namely internal or e screw producing a tensile force known as preload between the shank and the screw threads. Once achieving the adequate preload, the elastic recovery of the screw creates a clamping force (6, 15) to enable the restoration fastened to the abutment or implant. Implant manufacturers have recommended specific torque values for each abutment/prosthetic screw, which should be strictly adhered during the torquing procedure. As torque decreases below the manufacturer's value, there is an insufficient clamping force resulting in screw loosening.

Screw loosening is the most prevalent mechanical complication in screw-retained restoration and custom abutments. The phenomenon of the "settling effect" (1, 10, 14) also called "embedment relaxation" plays a vital role in screw biomechanics. Settling occurs when the rough metal parts flatten under load, as they are the main contacting surfaces when preliminary tightening torque is applied.

TABLE 5 | Basic and mean postcyclic loading Reverse Torque Values (postRTV2) of Group II test samples (Co-Cr screw-retained implant crown with the application of oral health care product)(GC Tooth Mousse).

Sample no.	PostRTV2 (Ncm)
GII 1	23.75
GII 2	24.21
GII 3	23.89
GII 4	23.81
GII 5	23.42
GII 6	24.01
GII 7	25.94
GII 8	23.03
GII 9	23.94
GII 1O	25.01
Mean/S.D	24.101/ ± 0.824

TABLE 6 | Basic and mean Reverse Torque Differences (RTD2) of Group II test samples (Co-Cr screw-retained implant crown with the application of oral health care product) (GC Tooth Mousse).

Sample no.	PreRTV2 (Ncm)	PostRTV2 (Ncm)	PostRTV2(-) PreRTV2 = RTD2 (Ncm)
GII 1	26.27	23.75	−2.52
GII 2	27.11	24.21	−2.90
GII 3	25.42	23.89	−1.53
GII 4	26.28	23.81	−2.47
GII 5	26.57	23.42	−3.15
GII 6	27.07	24.01	−3.06
GII 7	27.01	25.94	−1.07
GII 8	26.89	23.03	−3.86
GII 9	27.03	23.94	−3.09
GII 1O	26.11	25.01	−1.1
Mean/SD	26.576/ ± 0.553	24.101/ ± 0.824	−2.475/ ± 0.944

TABLE 7 | Comparative evaluation of the mean pre- and postcyclic loading Reverse Torque Values of Group I test samples (Co-Cr screw-retained implant crown without application of oral health care product) using the Paired 't' test.

GROUP I	Number of samples	Mean RTV1(Ncm)	*p*-value
Precyclic loading (preRTV1)	10	26.12	0.640
Postcyclic loading (postRTV1)	10	22.49	

*P value < 0.05 indicates significance

TABLE 8 | Comparative evaluation of the mean pre- and postcyclic loading Reverse Torque Value of Group II test samples Co-Cr screw-retained implant crown with the application of oral health care product (GC Tooth Mousse) using the Paired '*t*' test.

GROUP II	Number of samples	Mean RTV2(Ncm)	*P*-value
Precyclic loading (preRTV2)	10	26.57	0.779
Postcyclic loading (postRTV2)	10	24.10	

*P-value < 0.05 indicates significance

TABLE 9 | Comparative evaluation of the mean precyclic loading Reverse Torque Values of Group I test samples (Co-Cr screw-retained implant crown without application of oral health care product) (preRTV1) and Group II test samples (Co-Cr screw-retained implant crown with the application of oral health care product) (GC Tooth Mousse) (preRTV2) using the Independent 't' test.

GROUP	Number of samples	Mean/S.D Precyclic loading RTV (Ncm)	*p*-value
I (preRTV1)	10	26.12/ ± 0.49	0.069*
II (preRTV2)	10	26.57/ ± 0.55	

*P value < 0.05 indicates significance

This settling effect loosens the initial preload, making the screw vulnerable to loosen; thus, it is recommended that an abutment screw should be retightened ten minutes after its primary torque insertion. The loss of tightening torque has been estimated to be between 2 to 10% but studies have shown up to 20% (6, 14).

The correlation between the applied torque and screw preload is affected by many variables including screw material properties, screw diameter (14), screw configuration, and coefficient of friction. In clinical practice, variations in torque delivery system, force applied during manual tightening, and presence of contaminants (6, 13) are all possible sources of variation that contribute in attaining optimal preload at the implant–abutment/prosthetic joint.

In clinical dentistry, surface contamination of the implant screw threads and connection interfaces can be expected mainly during surgical and prosthetic phases of implant treatment (5). Saliva, blood, chlorhexidine, and povidone-iodine are commonly seen to come in contact with the implant components (5, 9, 11) and are found to alter the screw preload values.

Gumus et al. (13) observed that blood contamination may result in greater screw loosening in clinical practice because of significantly decreased RTV. This is because of high protein content and the presence of macromolecules such as fibrinogen and platelets in addition to blood viscosity, may contribute to the reduction of RTV.

Contaminants like metal debris (6), plaster/stone, or resin may get incorporated into the crevices of implant prosthetic components during the laboratory procedures and these particles may function as rough high spots in the

TABLE 10 | Comparative evaluation of the mean postcyclic loading Reverse Torque Values of Group I test samples (Co-Cr screw-retained implant crown without application of oral health care product) (postRTV1) and Group II test samples (Co-Cr screw-retained implant crown with the application of oral health care product)(GC Tooth Mousse) (postRTV2) using the Independent 't' test.

GROUP	Number of samples	Mean/S.D Postcyclic loading RTV (Ncm)	*p*-value
I (postRTV1)	10	22.49/ ± 0.86	0.00*
II (postRTV2)	10	24.10/ ± 0.82	

**P* value < 0.05 indicates; significance

TABLE 11 | Comparative evaluation of the mean Reverse Torque Difference values of Group I test samples (Co-Cr screw-retained implant crown without application of oral health care product) (RTD1) and Group II test samples (Co-Cr screw-retained implant crown with the application of oral health care product) (GC Tooth Mousse) (RTD2) using the Independent 't' test.

GROUP	Number of samples	Mean/S.D RTD (Ncm)	*p*-value
I (RTD1)	10	−3.63/± 0.91	0.034*
II (RTD2)	10	−2.47/± 0.94	

**P* value < 0.05 indicates significance

screws and could affect the preload values due to increased surface friction.

The implant screw access hole may become contaminated by several materials during a patient's routine home care hygiene activity (5, 6, 17). Dentifrices, oral rinses (5, 18) the artificial saliva, and varnishes are commonly used oral health care products. However, current literature is lacking in the study of the effect of contamination of prosthetic screws RTV by oral health care products.

Screw loosening can be quantitatively measured at different time intervals by recording the Reverse Torque Value (8, 23). It is the measurement of the remaining preload in the abutment screw. Measurement of Reverse Torque Value of a screw is important, as it suggests to the clinician about the torque necessary to loosen and tighten the screw. The closer it is to the primary torque, the better the maintenance of preload is. The Measurement of Reverse Torque Value can be done using a torque meter1 either analog or a digital type (8, 11, 21).

Most of the studies are related to changes in Reverse Torque Values after cyclic loading of titanium standard abutments after contamination with metal debris, artificial saliva, blood, etc. Few studies have evaluated pre- and postloading reverse torque values of abutment \prosthetic screws with a dry and wet environment protocols achieving varied results (24).

UCLA plastic abutments compatible with the implant analogs from the same manufacturer were used to avoid the risk of using prosthetic screws from other systems on the screw loosening as recommended by Kim et al. (25)

GC Tooth Mousse was used as an oral health care product in this study, which is a unique product containing Amorphous Calcium Phosphate (ACP) and Casein PhosphoPeptide (CPP), which is obtained from milk casein. Several *in vitro* and *in vivo* studies have demonstrated that treatment with ACP-CPP improves increase in enamel remineralization. This product is also recommended for patients exhibiting high caries activity, hypersensitivity, and xerostomia.

Nigro et al. (24) compared the screw loosening measured in both dry screws and screws exposed to artificial saliva and found higher mean RTV for the wet group than for the dry group. This could be due to the fact that saliva acts as a lubricating agent and reduces the friction between the metal mating parts. These findings are consistent with the results obtained in this study.

Duarte et al. (17), reported an increased reverse torque value after immersing the abutment screws in fluoridated artificial saliva and this increase was explained on the basis of deposition of corrosion layer between the metallic surfaces. Sara Koosha et al. (5) compared the RTV of abutment screws at implant abutment connection, contaminated with chlorhexidine mouthwash (CG), saliva (SG), blood (BG), fluoride (FG), and control group with no contamination (CG) and found increased RTV for test samples contaminated with chlorhexidine (CG). This is in divergence with the results obtained in this study and could be due to the study design, test materials employed, and study environment.

Oral health care products such as commercial dentifrices, topical gels/varnishes, and mouthwashes are commonly used by patients or through professional care. Micromovements at the implant–abutment/prosthetic interface during functional activity and percolation of oral fluids is expected (26, 27). In this study, Group II test samples coated with GC Tooth Mousse yielded a higher detorque value following cyclic loading, which was found to be statistically significant. These findings could be ascribed to the lubricating effect of the oral health care product on the internal and external threads of the implant and prosthetic screw, thereby reducing the friction and resulting in higher preload.

Arshad et al. (10) compared screw loosening between non-coated and coated abutment screws using an industrial grade adhesive following a 1-year cyclic loading period and found significantly higher detorque values for coated screws. This is in line with the results obtained in this study. The Reverse Torque Difference value was calculated to assess the range of torque loss in Group I and Group II samples, thereby quantifying the screw loosening. Group II had a significantly lesser reverse torque difference between pre-and postcyclic loading Reverse Torque Values. This indicated that the range of torque loss was significantly greater for Group I as compared to Group II. This difference could be due to the limited sample size employed in this study. Increased sample size could also give different interpretations. This needs to be investigated further in future studies. Thus, the null hypothesis was rejected due to the significant differences in reverse torque values in both the test groups.

Although cyclic loading was performed to simulate the oral environment in this study, the implant–prosthetic interface can be contaminated with more than one contaminant simultaneously and should be taken into consideration in further studies. However, the contamination protocol in this *in vitro* study may not completely reflect an actual clinical condition, but the results obtained will provide clinicians with a better understanding of the effect of probable fluid contamination at the implant–abutment/prosthetic interface.

Further clinical research evaluating the effect of cyclic loading on titanium prosthetic screw loosening, comparing oral health care products with varying concentration, using a larger sample size and longer loading protocols depicting oral conditions are suggested to validate the results obtained in this study.

Conclusion

Within the limitations of this study, both non-coated and coated titanium prosthetic screws exhibited a reduction in preload after cyclic loading. This preload loss, which is indicative of prosthetic screw loosening, was significantly greater for Group I than for Group II after cyclic loading. The higher postload Reverse Torque Values in the coated screws may be explained on the basis of a decrease in coefficient of friction, thus reducing the possibility of screw loosening.

References

1. Attiah E, AlGendy A, Mostafa T. Effect of dynamic cyclic loading on screw loosening of retightened versus new abutment screw in both narrow and standard implants (in-vitro study). *Int J Implant Dent.* (2020) 6:30.
2. Balshi T, Wolfinger G. Immediate loading of Brånemark implants in edentulous mandibles: a preliminary report. *Implant Dent.* (1997) 6:83–8.
3. Dincer Kose O, Karataslı B, Demircan S, Kose T, Cene E, Aya S, et al. In vitro evaluation of manual torque values applied to implant-abutment complex by different clinicians and abutment screw loosening. *Biomed Res Int.* (2017) 2017:7376261.
4. 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) 15:164–71.
5. Koosha S, Toraji S, Mostafavi A. Effect of fluid contamination on the reverse torque values of abutment screws at implant-abutment connections. *J Prosthet Dent.* (2020) 123:618–21.
6. Lee H, Alkumru H, Ganss B, Lai J, Ramp L, Liu P. The effect of contamination of implant screws on reverse torque. *Int J Oral Maxillofac Implants.* (2015) 30:1054–60.
7. Gómez-Polo M, Ortega R, Gómez-Polo C, Celemin A, Del Rio Highsmith J. Factors affecting the decision to use cemented or screw-retained fixed implant-supported prostheses: a critical review. *Int J Prosthodont.* (2018) 31:43–54.
8. Alnasser A, Wadhwani C, Schoenbaum T, Kattadiyil M. Evaluation of implant abutment screw tightening protocols on reverse tightening values: An in vitro study. *J Prosthet Dent.* (2021) 125:486–90.
9. Alsubaiy E. Abutment screw loosening in implants: A literature review. *J Family Med Prim Care.* (2020) 9:5490–4.
10. Arshad M, Shirani G, Refoua S, Rahimi Yeganeh M. Comparative study of abutment screw loosening with or without adhesive material. *J Adv Prosthodont.* (2017) 9:99–103.
11. Goldstein G, Ghoujal B, Abdullah S. An in vitro assessment of the accuracy of new and in-use torque-limiting devices. *J Prosthet Dent.* (2020) 124:716–9.
12. Ebadian B, Fathi A, Khodadad S. Comparison of the effect of four different abutment screw torques on screw loosening in single implant-supported prosthesis after the application of mechanical loading. *Int J Dent.* (2021) 2021:3595064.
13. Gumus H, Zortuk M, Albayrak H, Dincel M, Kocaagaoglu H, Kilinc H. Effect of fluid contamination on reverse torque values in bone-level implants. *Implant Dent.* (2014) 23:582–7.
14. Huang Y, Wang J. Mechanism of and factors associated with the loosening of the implant abutment screw: A review. *J Esthet Restor Dent.* (2019) 31:338–45.
15. Yao K, Kao H, Cheng C, Fang H, Yip S, Hsu M. The effect of clockwise and counterclockwise twisting moments on abutment screw loosening. *Clin Oral Implants Res.* (2012) 23:1181–6.
16. Bidra A. Prosthodontic safety checklist before delivery of screw-retained and cement-retained implant restorations. *J Prosthet Dent.* (2018) 119:193–4.
17. Duarte A, Neto J, Souza J, Bonachela W. Detorque evaluation of dental abutment screws after immersion in a fluoridated artificial saliva solution. *J Prosthodont.* (2013) 22:275–81.
18. Paolantonio M, Perinetti G, D'Ercole S, Graziani F, Catamo G, Sammartino G, et al. Internal decontamination of dental implants: an in vivo randomized microbiologic 6-month trial on the effects of a chlorhexidine gel. *J Periodontol.* (2008) 79:1419–25.
19. Richter K, Kragh K. *Antibiofilm Strategies: Current and Future Applications to Prevent, Control and Eradicate Biofilms.* Berlin: Springer Nature (2022). 569.
20. Rathe F, Ratka C, Kaesmacher C, Winter A, Brandt S, Zipprich H. Influence of different agents on the preload force of implant abutment screws. *J Prosthet Dent.* (2021) 126:581–5.
21. Yu P, Li Z, Tan X, Yu H. Effect of sealing gel on the microleakage resistance and mechanical behavior during dynamic loading of 3 implant systems. *J Prosthet Dent.* (2022) 127:308–17.
22. Sahin C, Ayyildiz S. Correlation between microleakage and screw loosening at implant-abutment connection. *J Adv Prosthodont.* (2014) 6:35–8.
23. Kim E, Shin S. Influence of the implant abutment types and the dynamic loading on initial screw loosening. *J Adv Prosthodont.* (2013) 5:21–8.
24. Nigro F, Sendyk C, Francischone C Jr., Francischone C. Removal torque of zirconia abutment screws under dry and wet conditions. *Braz Dent J.* (2010) 21:225–8.
25. Kim K, Lim Y, Kim M, Kwon H, Yang J, Lee J, et al. Variation in the total lengths of abutment/implant assemblies generated with a function of applied tightening torque in external and internal implant-abutment connection. *Clin Oral Implants Res.* (2011) 22:834–9.
26. Bacchi A, Regalin A, Bhering C, Alessandretti R, Spazzin A. Loosening torque of Universal Abutment screws after cyclic loading: influence of tightening technique and screw coating. *J Adv Prosthodont.* (2015) 7:375–9.
27. Dixon D, Breeding L, Sadler J, McKay M. Comparison of screw loosening, rotation, and deflection among three implant designs. *J Prosthet Dent.* (1995) 74:270–8.