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Mechanical evaluation of complete arch mandibular implant supported fixed prosthesis abutment screws following repetitive loading: An *In vitro* investigation

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Abstract
Introduction: The goal of modern dentistry is to restore the normal contour, function, comfort esthetics, speech, and health regardless of the atrophy, disease, or injury of the stomatognathic system.
Methodology: The implants were arranged in an arch, simulating the clinical condition of restoring an edentulous mandible with uniform 10 mm interimplant spacing and an anterior abutment distance (fulcrum line) of 9 mm. The implant locations were reproduced by laser scanning the jaw model. The framework was designed from the position of the placed implants and with the addition of bilateral 15 mm long distal extension cantilevers. For the investigation, four identical frames were created and randomly chosen from each group, alternating between loaded and unloaded ones. Five 4.310 mm implants were individually screwed to a framework to assure passive fit of the framework to the implants in order to create a single specimen of a test group. Results: The ANOVA showed that there was a significant (P=.002) relationship among the loading and screw location. The 2 levels of loading were contrasted independently at each of the 5 screw positions with a Bonferroni-adjusted significance level of.05/5=.01 in order to analyse simple impacts. Conclusion- No significant difference was found in torque/ detorque values between loaded and non-loaded conditions, except the centre screw location, where the loaded screws demonstrated greater potential loosening than their non-loaded counterpart.

Keywords: Detorque, mechanical evaluation, loading, screw position

Introduction

No matter the cause of stomatognathic system atrophy, sickness, or damage, contemporary dentistry aims to restore the natural contour, function, comfort, aesthetics, health, and speech [1]. But more teeth a patient has missing, the more challenging it is to accomplish this with conventional dentistry. Nowadays, the practise of anchoring alloplastic substance into the jaws to give support and retention for prosthetic replacements of missing teeth is known as dental implantology [2]. Endosteal dental implants are currently expected to become a common treatment option in dentistry due to generally encouraging experiences and the creation of new knowledge. A variety of implant forms are now accessible for use in the rehabilitation of various clinical conditions as a result of research-driven advancements in implant designs, materials, and procedures. When using a traditional total denture prosthesis, the patient's functionality may be just 60% of what it was when they had natural teeth. Compared to conventional restorations, implant prosthetics provide a more predictable method for therapy [3].

Complete-arch prosthesis are currently being used to treat a large number of patients with edentulism who are receiving implants. Except for prosthesis repair, these prostheses are usually left in place and screwed to the implants or abutments [2]. According to several investigations, the most frequent issue with dental implants after osseointegration is abutment screw loosening [3]. There are various estimated rates of loosening, with instances reaching 12.5%. A gap between the approximated components may be created by a loosening screw, which could result in a loss of closing and the growth of microbes [4].

Just when external pressures are stronger than the force holding the pieces together will a tightened screw begin to loosen. Preload is the amount of force required to keep substrates together under all static and functional circumstances. Preload is created in the abutment screw as torque exerted, compressing the abutment-implant assemblage and giving the parts being linked a compressive, clamping effect [7]. A smaller amount of force is required to release (detorque) the screw because there is fewer thread interference and attrition than there was during the initial tightening process [8, 9].

The stress in the implant-abutment system is changed by the friction coefficient, which also has a major impact on the screw preload value [10]. The abutment screw has been coated with dry lubricant in an effort to further reduce frictional resistance. A coated titanium alloy screw is one illustration. It has a thin layer of polytetrafluorothylene (PTFE, also known as Teflon), which is said to reduce the frictional coefficient by 60% [11].

For a simulated five-implant-supported mandibular prosthesis, the aim of this *in vitro* study was to assess and compare changes in screw initial lightening torque integrity and physical appearance under long-term dynamic fatigue loads and when loading is not performed. The study's main hypotheses were that screw torque loss (DT) would be significantly higher after cyclic loading compared to the non-loaded control group, that torque loss would differ significantly depending on where the implants were placed within the arch, and that loaded implant screw matting surfaces would look significantly worse than the non-loaded control group.

Methodology

This study was carried out at the Dr. HRSM Dental College's Department of Prosthodontics and Crown & Bridge in Hingoli, Maharashtra. A milling machine and an implant drilling apparatus were mounted to a surveyor table and used to simulate the placement of an implant (Fig. 1). The implants were set up in an arch shape to mimic the restoration of an edentulous mandible, with anterior abutment distances (fulcrum lines) of 9 mm and homogeneous interimplant spacing of 10 mm. The laser-scanned jaw model served as a replica of the implant placements. Bilateral 15 mm long distal extension cantilevers were added to the framework, which was constructed based on the placement of the implants (Fig. 2).

In order to use four similar frameworks in the research, the loaded and unloaded ones were alternated among the groups of four (Procera Production Centre). Five 4.310 mm implants were individually fastened to a framework using screws (TiTite; Nobel Biocare) to ensure passive fit of the framework to the implants in order to create a single specimen of a test group (Fig. 3). The emulated mandibles were manufactured using a specially built 3-dimensional printer and a triangular hollow base made of thermoplastic resin (ABS round cord; New Image Plastics) that was created using computer software. A light-polymerizing composite resin with an elastic modulus of 10.5 GPa was used to fill each implant-framework complex, which was then set into the hollow base. This resin's elastic modulus is similar to that of mandibular bone that has been exposed to buccal-lingual loading (10.8 GPa). A passive fit test was conducted after filling (Fig. 4), and it was repeated five times. The screws were taken out and substituted with brand-new, titanium alloy screws (TorqTite 29475; Nobel Biocare) that were already index marked. To standardise the process of tightening or loosening each screw, the implant site (1-2-3-4-5) was used to identify each screw. Sequential torque tightening was used.

A typical, manufacturer-recommended torque of 35 Ncm was used to tighten screws. A calibrated, electronic digital torque wrench was used to tighten, wait 10 minutes, and then retorque to the same value. To prevent any lateral (off-axis) movement during screw tightening and loosening, the torque wrench was securely held vertically in a surveyor. This reduced fluctuation in torque measurements. Using data gathering software, the peak torque value imparted to each screw was captured in real time.

Fig 1: Placement of implant in simulated mandible before design of titanium framework bar.

Fig 2: Fabricated milled-titanium framework with 4 locator attachments (arrows) that received loading force (test) or not (control).

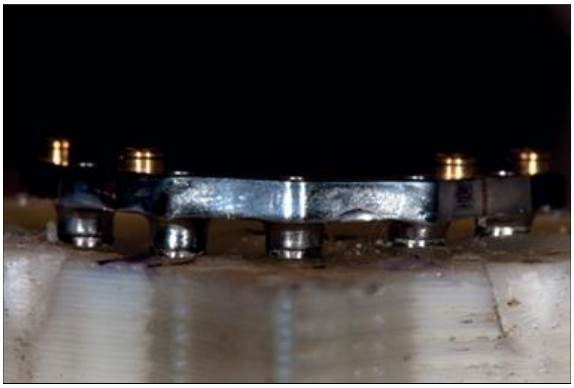

Fig 3: Milled framework attached to implants by screws (frontal view) and ready to be embedded into triangular mandibular holding device.

Fig 4: Close-up view of milled framework attached to implants by screws and embedded into filled triangular mandibular holding device.

Results

The ANOVA revealed that the interaction between loading and screw position was significant (P=.002). Thus, simple effects were analyzed; that is, the 2 levels of loading were compared separately at each of the 5 screw positions with a Bonferroni-adjusted significance level of. 05/5=.01. In addition, DT values of the 5 screw positions were compared separately for each of the 2 levels of the loading factor with a Bonferroni-adjusted level of. 05/2=.025.

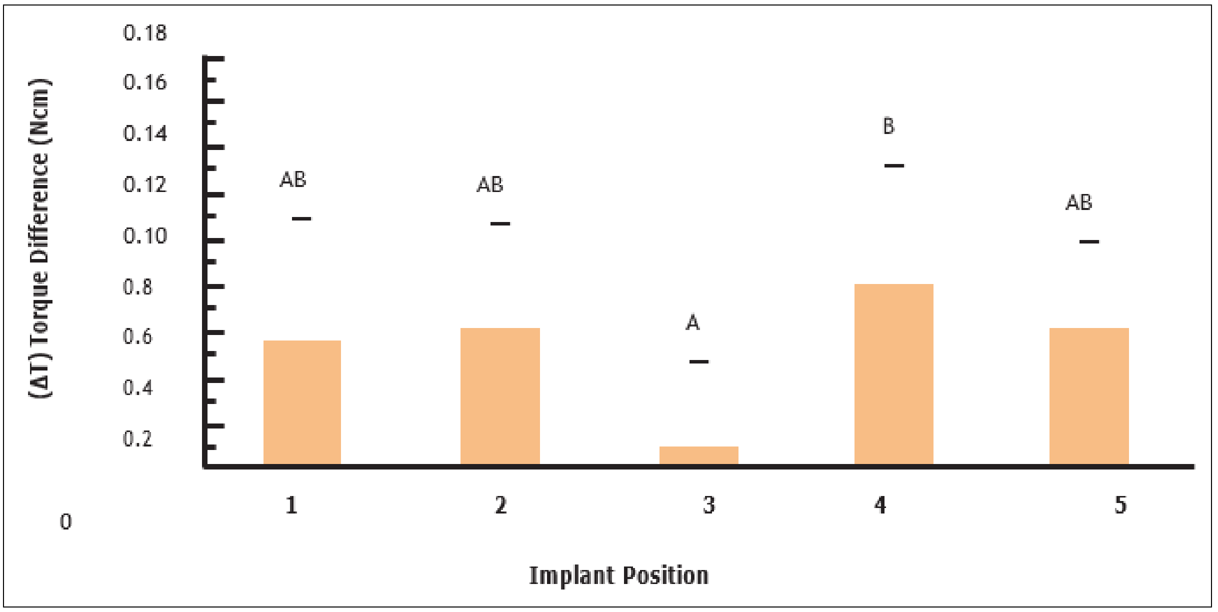

Fig 5: Comparison of unloaded (control) DT values among different screw positions in framework (n=9). Groups identified with similar uppercase letters were not significantly different. Vertical bar=-1 standard deviation.

Table 1: Mean (±SD) difference in number of threads with debris (after testing minus before) by loading condition and implant position based on a continuous rage of 0 (least) to 8 (most).

Loading condition	Implant position	n	Mean ±SD	Minimum	Maximum
Control	1	5	4.2±2.2	1	6
	2	5	2.8 ±1.3	1	4
	3	5	2.8 ±2.3	0	6
	4	5	5.4 ±1.5	3	7
	5	5	2.8 ±1.8	1	5
Loaded	1	5	3.0 ±1.7	0	4
	2	5	3.0 ±2.2	0	6
	3	5	4.6 ±1.1	3	6
	4	5	3.8 ±1.6	1	5
	5	5	4.8 ±1.6	2	6
Pooled	1	10	3.6 ±2.0	0	6
	2	10	2.9 ±1.7	0	6
	3	10	3.7 ±1.9	0	6
	4	10	4.6 ±1.7	1	7
	5	10	3.8 ±1.9	1	6

Table 2: Mean (±SD) difference in number of striated threads (after testing minus before) by loading condition and implant position based on a continuous rage of 0 (least) to 8 (most)

Loading condition	Implant position	n	Mean ±SD	Minimum	Maximum
Control	1	5	1.2 ±1.6	0	4
	2	5	0.8 ±1.6	-1	3
	3	5	0.4 ±0.9	-1	1
	4	5	0.8 ±0.4	0	1
	5	5	0.6 ±0.9	0	2
Loaded	1	5	1.0 ±1.0	0	2
	2	5	1.2 ±0.8	0	2
	3	5	0.6 ±1.1	-1	2
	4	5	0.6 ±1.8	-1	3
	5	5	0.6 ±1.1	-1	2
Pooled	1	10	1.1 ±1.2	0	4
	2	10	1.0 ±1.2	-1	3
	3	10	0.5 ±1.0	-1	2
	4	10	0.7 ±1.3	-1	3
	5	10	0.6 ±1.0	-1	2

Table 3: Mean (±SD) difference in number of homogeneous threads (after testing minus before) by loading condition and implant position based on a continuous rage of 0 (least) to 8 (most)

Loading condition	Implant position	n	Mean ±SD	Minimum	Maximum
Control	1	5	1.8 ±1.6	-1	3
	2	5	1.2 ±1.3	-1	2
	3	5	0.0 ±0.7	-1	1
	4	5	1.0 ±1.6	-1	3
	5	5	0.6 ±2.5	-3	3
Loaded	1	5	1.6 ±2.5	-1	4
	2	5	1.6 ±1.1	0	3
	3	5	1.0 ±1.9	-2	3
	4	5	1.6 ±1.5	-1	3
	5	5	1.4 ±1.5	-1	3
Pooled	1	10	1.7 ±2.0	-1	4
	2	10	1.4 ±1.2	-1	3
	3	10	0.5 ±1.4	-2	3
	4	10	1.3 ±1.5	-1	3
	5	10	1.0 ±2.0	-3	3

Discussion

The findings from the tests show that the first and second study hypotheses were only partially disproved, indicating that loading under physiological settings may result in lower detorque values across all implant sites in the dental arch and consequently higher screw loosening. The pattern of torque differences seen in the unloaded, control condition suggests that the screw-tightening sequence may have an impact on screw loosening (DT) (Figs. 5). The loaded group showed a difference in the potential for screw loosening between the distal extensions and screws anterior to them because the screws nearest to the cantilevers showed the lowest DT values (unscrewed the least) and the screws farthest from the most distal locations provided the greatest numbers (unscrewed the most).

The middle screw was supposed to have the biggest difference in DT, however its value was not noticeably different from that of the screws on either side. These results have therapeutic implications since it appears that loading a framework alters the initial pattern of torque/detorque differences that was observed in the nonloaded control group and replaces it with a new one. Focus is on the middle screw (Position 3), which had a much lower DT value than the other spots in the nonloaded control group.

Contrary to what was observed in the loaded circumstance, the trend in DT among implant locations showed a V-shaped pattern. Since tension is not distributed evenly among the screws of the framework before they are put into service, this conclusion implies that forces aren't distributed equally among them. All models in the investigation were subjected to a linear torque sequence. According to one research, screws should be tightened crosswise when doing so [12]. Another investigation advised tightening the screws one at a time, beginning with the implant that was closest to the midline and finishing with the two terminal screws [13]. According to a separate investigation, neither the axial forces nor the bending moments were statistically significantly affected by the order in which the screws were tightened [14].

The third investigation's hypothesis was not confirmed, indicating that the visual appearance of the matting surfaces of the screw after loading, including the presence of debris from the Teflon coating's delamination, which is not significantly worsened by loading. Regarding either the test condition or implant position, no statistically significant changes in screw integrity were detected for any of the analysed parameters. Nevertheless, numerous screws showed an increased amount of debris after use in both the loaded and unloaded circumstances based solely on visual inspection. Surface debris on as-manufactured screw-threaded surfaces is possibly the result of the milling process [15], which could potentially affect the increase in frictional resistance for screw insertion and removal. For the loaded condition, the debris could be a result of implant thread wear with transmission of titanium particles from the implant to the prosthetic screw surface, which could accelerate the settling effect [11].

The use of just one implant manufacturer and the high degree of variability in the analysed outcomes are two factors that limit the current investigation. The current study utilised only 4 distinct frameworks, but they were chosen at random by alternating between loaded and unloaded groups throughout the experiment. As a result, it was not able to investigate the role of a particular framework as a contributing element. Individual frameworks for each model were not deemed necessary or that they would significantly influence the test results because data indicate that this type of titanium framework can withstand prolonged use without significant change [16, 17, 18].

Future research should investigate the role of torque sequence and load on the potential for a screw to loosen. Furthermore, instead of removal, the screw could be only retightened to its initial torque value and then analysed after various time periods and loading scenarios.

Conclusion

Except for the centre screw position, where the loaded screws showed a higher tendency for loosening than their non-laden counterpart, there was no discernible variation in torque/detorque values between the loaded and unloaded conditions. In the unloaded situation, a considerable variation in torque/detorque values was detected among implant positions, with the central screw site displaying the least difference (and therefore the least risk of screw loosening). In the loaded situation, there was a considerable variation in the torque/detorque values between implant places, with the most distal implant locations—those closest to the cantilever—exhibiting the lowest values and the lowest risk of screw loosening.

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