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FULL PAPER

Comparing loosening between cement retained and screw retained implant supported crowns: a dynamic non-linear finite element analysis

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Titanium root form implants are widely accepted because of the advantages of their mechanical properties. This study compared the screw loosening between two types of implant supported crowns (cement retained and screw retained) at the location of left lower first molar, using finite element method in a nonlinear analysis. The Dentis system was used for modeling of the implant, abutment and suprastructure. The amount of preload displacement was almost the same for both types of abutments. Applying force in any direction reduced the amount of downward preload displacement and decreased abutment-implant stability. In the cement retained crown, the amount of inner abutment displacement was always less than the screw head displacement by applying vertical, oblique and vertical-horizontal loads, so the stability of the abutment-implant complex was maintained. In the screw retained crowns under vertical-horizontal load the amount of displacement at the screw head and inner side of abutment was close to each other and this put the screw on the verge of loosening. However, under oblique pressure of 100 N, the inner abutment displacement exceeded the screw head displacement and the screw was loosened. Under vertical loading of 100 and 150 N, the stability of implant abutment was maintained. Screw loosening is less likely to occur under vertical load compared with oblique load. The cemented retained crowns have a higher biomechanical stability than screw retained crowns.

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KEYWORDS

Abutment; cemented; screw; loosening; finite element analysis.

Introduction

Titanium root form implants are widely accepted because of the advantages of their mechanical properties and their excellent anchorage in the jawbone [1]. Nowadays, the prosthodontic rehabilitation of implants can be accomplished through a cemented or screw-retained restoration. The selection of the prostheses still usually depends on the preferences of the clinicians [2]; however, different advantages and disadvantages have been clarified for each type [3].

Cement retained restorations have advantages including good esthetic appearance due to absence of the occlusal hole, correct passive fit and better fracture resistance of the ceramic veneering [3,4,5,6]. On the other hand, cemented retained crowns need an adequate prosthetic space, and in several cases, there is difficulties in the removal of the prostheses [7].

Many clinicians choose the screw-retained restorations because of preventing the presence of residual cement and eliminating the complications in the soft tissue [8,9]. However, the hole for accessing the screw in the occlusal surface of the crown lead to a non-esthetic restoration and can interfere with the normal occlusal contacts [3,9]. Furthermore, the fracture resistance of the porcelain may be lower than cement retained crowns, because of the presence of the screw access [10].

Prosthetic complications are the disadvantages of implants, which may develop during the clinical life of the implant. Such complications are loosening of the fixing screw or the abutment, fracture of the abutment or the implant, decementation of the crown, chipping of the veneering porcelain and so on [11,12,13]. With regard to the history, the most common complication in screw- retained restorations is the loosening of the screw. Similarly, in cement-retained restorations, a problem is the loosening of the abutment screw under the crown [11,14,15]. The results described in different studies are incompatible. Some report higher prevalence of screw loosening in screw-retained (15,16,17) and others in cement-retained restoration [11].

Clinical studies to investigate the loosening of the fixing screw or abutment are time consuming and expensive, so dental implants must be tested using a systematic approach. The finite element method is non-invasive, computational numeric method that provides the analysis of different types of internal or external stresses, strains, and displacements in various site of the studied models. The finite element technique is frequently employed in implant dentistry and is used in a wide spectrum of simulations [18,19].

Due to contradictions described previously about screw loosening in cemented or screw-retained restoration and time consuming and expensive characteristics of clinical studies and lack of study about CCM UCLA abutment, this study aimed at comparing screw loosening between cement retained and screw retained implant supported crowns, using a dynamic non-Linear Finite Element Analysis.

Material and method

The Dentis system was used for modeling of the implant, abutment and suprastructure. Fixture (5/2 mm*10 mm), couple abutment (height=5.5, G/H=1, diameter=4.5 mm) and UCLA abutment (G/H=1 mm, diameter=4.5) were used and UCLA abutment was CCM(Cobalt Chromium Molybdenum) type. First, wax up of superstructure pattern was done using UCLA abutment. Then, the wax up pattern was cylindered inside a phosphate-bonded casting investment (Ticonium, Albany, NY, USA), and casting was performed by a nickel–chromium alloy (BEGO, Germany). Ni-Cr suprastructure was scanned by Dental laboratory 3D scanner (rainbowTM Dentium, USA). Using Exocad software, suprastructure of cemented restoration was designed completely similar to that of screw-retained restoration and its resin pattern was fabricated with 3D-printer device. Casting of resin pattern was performed by a nickel–chromium alloy (BEGO, Germany).

Implants, abutments, abutment screws, suprastructures and connections were precisely measured by a profile projector, and dimensions were achieved. The resolution of this device is about 0.01 mm, and the ×50 magnification was used. CATIA software V5R14 (Dassault System, UK, 2009) used for preparing models. After completion of the external design of the prostheses, a layer with 1.50 mm thickness was added to the outer surface of the entire volume of suprastructures, which was associated with ceramic layer. The screw access was filled with composite resin. For the cement-retained prosthesis, a homogeneous layer of 25 mm thick corresponding to zinc phosphate cement was added between the Ni-Cr suprastructure and abutment [20].

All the models were transmitted to ANSYS software (Ansys Workbench 14) and the connection method was described using contact elements. The implant– screw, implant–abutment, and screw–abutment connections are of friction type, and abutment–suprastructure connection is considered as a complete connection without displacement. The 400 N force equivalent to 30 N.cm torque was applied as preload force (21). Considering the boundary conditions, all the environmental nodes surrounding the bone were fixed to avoid the movement of the model during the load application procedure. The mechanical characteristics of each material were assigned for the software [Table 1].

TABLE 1 mechanical characteristics of each material

Material	Young's modulus (GPa)	Poisson ratio	Reference
Titanium abutment, implant and screw	**115**	**0.35**	**[21]**
Ni-Cr Suprastructure	**150**	**0.26**	**[21]**
Porcelain	**68/9**	**0.28**	**[20]**
Zinc phosphate cement	**17**	**0.35**	**[20]**
Composite sin	**7**	**0.20**	**[20]**
CCM(Cr-Co-Mo)	**196**	**0.25**	**[22]**

Then forces in four ways were applied on models [Table 2]. The pattern of loading was time dependent and transient in 1 second [Figure 1]. FEM data collection was carried out by ANSYS software. The movements associated with the abutment screw loosening were evaluated by determining displacements of head screw and inner surface of abutment. It should be noted that this study did not need statistical analysis.

TABLE 2 Direction and quantity of applied forces

Loading direction	Loading forces (N)	Refrence
Vertical	100	[20]
Vertical	150	[23]
Oblique (45 degree)	100	[20]
Vertical & Horizontal	100-50	[24]

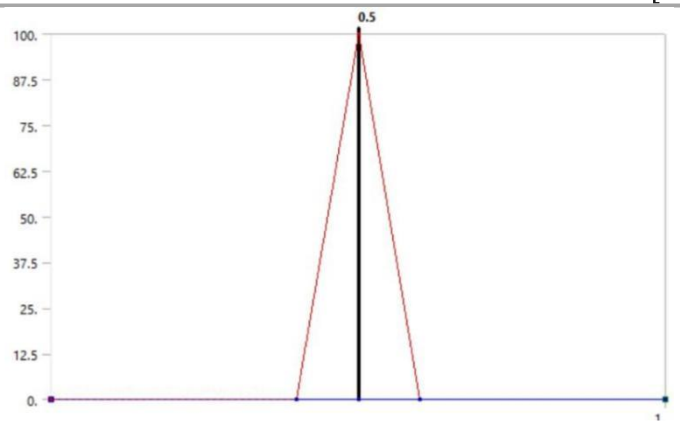

FIGURE 1 Pattern of time dependent loading for 100 N vertical force

Results

Displacements were assessed at 0.5 second when maximum load was applied to the suprastructure and at 0.1 second when no force was applied to the suprastructure. Displacement in 0.1 second was caused by 400-N preload, which is equivalent to a 30N.cm torque applied to the screw, so it was similar for each implant supported restoration in all 4 types of loadings. Displacement in 0.5 second is caused by applying 400-N preload (30 N.cm torque) to the screw and maximum load to the suprastructure. Displacements in the head of screw and inner side of abutment were analyzed. Relative displacement between head of screw and inner surface of abutment were associated with screw loosening. A decrease in this variable showed that applied initial preload was neutralized and screw loosening was progressed. The amount of displacements by applying loads with different values and directions is presented in Tables 3 and 4.

TABLE 3 The amount of displacements in cement retained restoration, under the influence of loads with different values and directions

Cement retained restoration	Preload force	100 N vertical force	150 N vertical force	100 Nvertical & 50 N horizontal force	100 N oblique force
Screw head Displacement (μm)	7.7	8.5	9.3	9.7	10.4
Inner surface of abutment Displacement (μm)	1.3	2.8	4.5	6.8	8.7
Screw loosening	No	No	No	No	No

TABLE 4 The amount of displacements in thescrew retained restoration, under the influence of loads with different values and directions

Screw retained restoration	Preload force	100 N vertical force	150 N vertical force	100 Nvertical & 50 N Horizontal force	100 N oblique force
Screw head displacement(μm)	7.7	10.5	9.4	12.7	14
Inner surface of abutment displacement(μm)	1.8	5.8	5.3	12.3	14.6
Screw loosening	No	No	No	Screw on the verge of loosening	Yes

Analysis of Preload displacement

The amount of preload displacement was almost similar for both types of restorations (7.7 μm on the screw head and 1.3-1.8 μm on the inner side of abutment). In other word, the preload force (30 N/cm) caused the implants to move 7.7 μm toward the bone in the longitudinal axis [Figures 2 and 3].

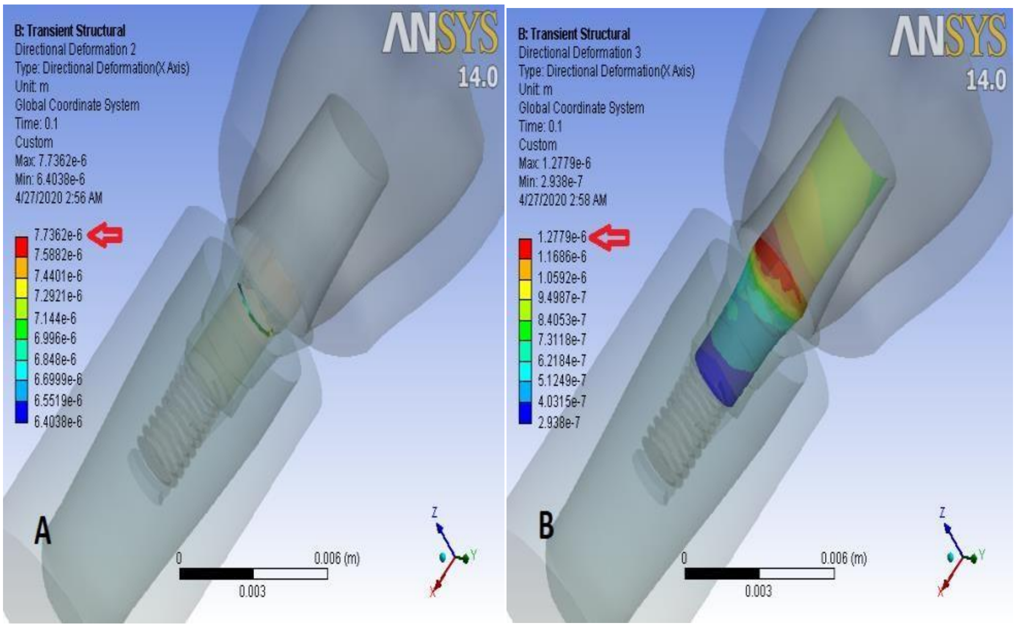

FIGURE 2 The preload displacement at the time of 0.1 seconds, before maximum loading for cement retained restoration. The maximum displacement in the head screw toward the bone in the longitudinal axis (1A). The maximum displacement in the inner side of abutment (1B)

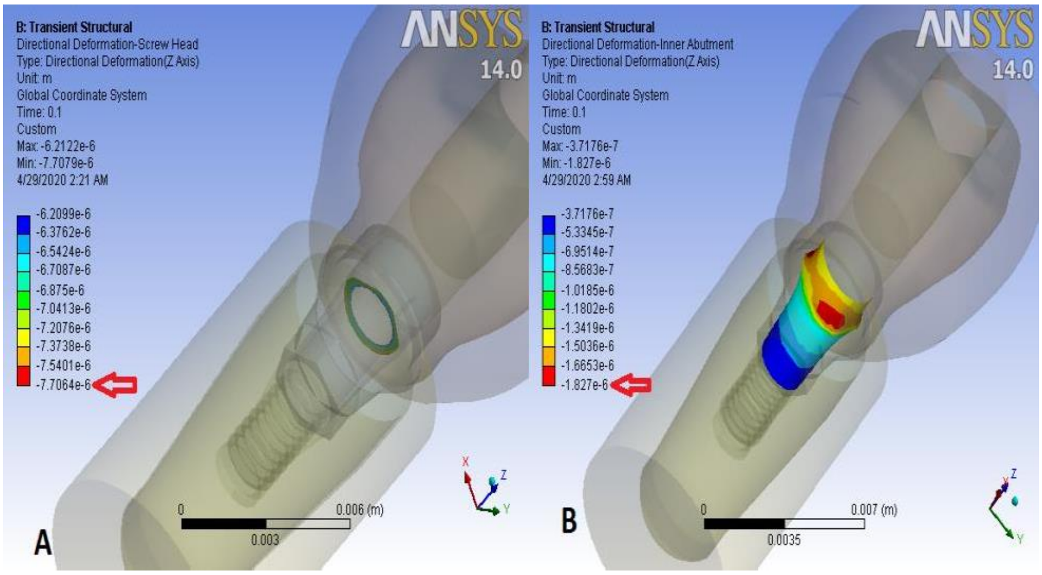

FIGURE 3 The preload displacement at the time of 0.1 seconds, before maximum loading for screw reatined restoration. The maximum displacement in the head of screw toward the bone in the longitudinal axis (1A). The maximum displacement in the inner side of abutment (1B).

Analysis of displacements by applying vertical load of 100 N

Displacement at the head of screw in the Screw retained restoration was higher than that of cement retained restoration (10.5 μm VS 8.5 μm). In both type of restoration, the amount of displacement at the inner side of abutments is less than screw head of abutment, so the stability of the implant-abutment complex was remained [Figures 4 and 5].

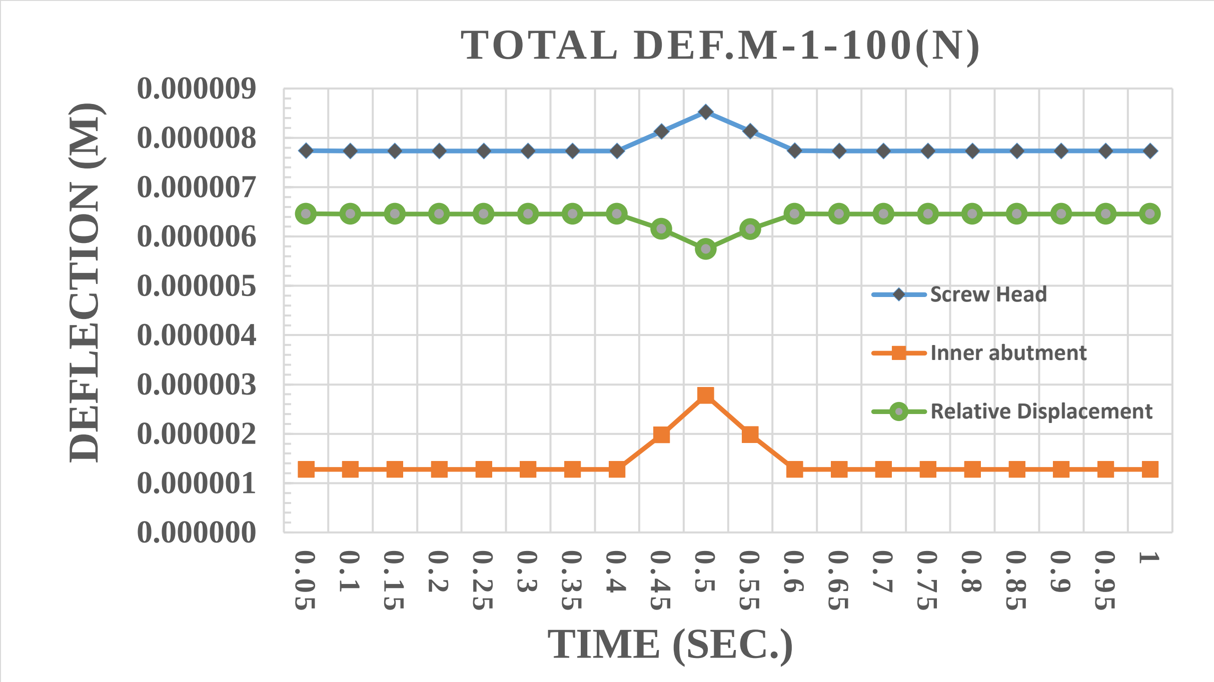

FIGURE 4 The amount of displacement in the screw head and inner side of abutment of cement retained restoration under vertical load of 100 N

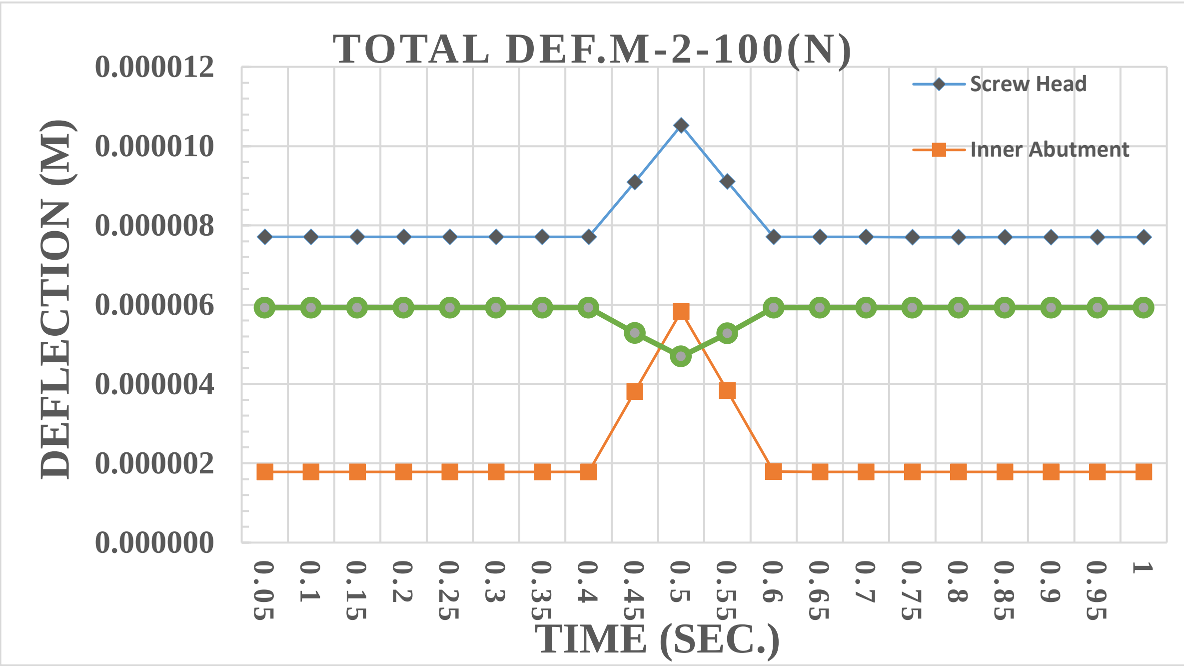

FIGURE 5 The amount of displacement in the screw head and inner side of screw retained restoration under vertical load of 100 N

Displacement analysis by applying vertical load of 150 N

The amount of displacement at the head of the screw was almost the same in both types of abutments (9.3 μm VS 9.4 μm). Under vertical load of 150 N, screw loosening did not occur in both models of restorations [Figures 6 and 7].

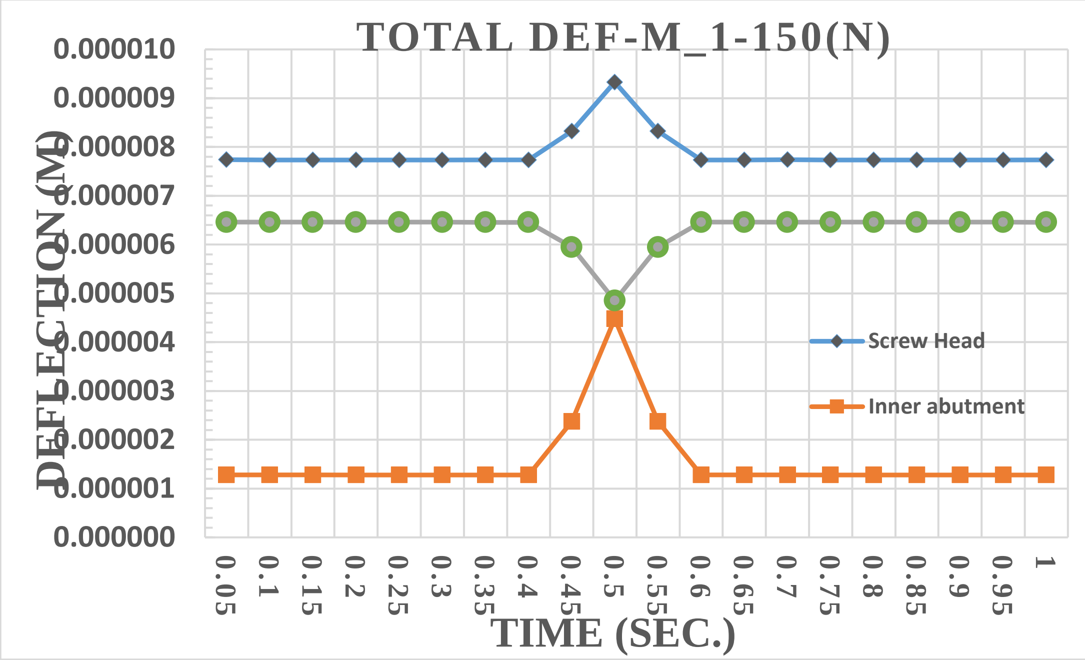

FIGURE 6 The amount of displacement at the head of screw and inner side of abutment in cement retained restoration under vertical load of 150 N.

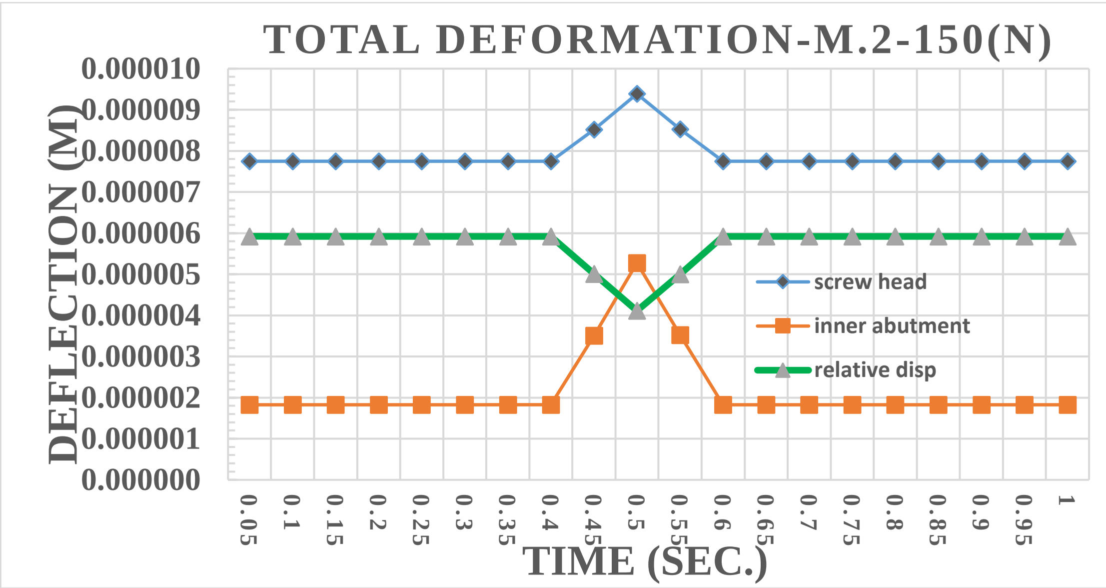

FIGURE 7 The amount of displacement at the head of screw and inner side of abutment in screw retained restoration under vertical load of 150 N.

Displacement analysis by applying concomitant vertical (100 N) and horizontal (50 N) load

The amount of displacement at the head of screw and inner side of abutment in screw retained restoration was greater than that of cement retained and in screw retained restoration the difference in displacement between the head of the screw and inner side of abutment was lower (12.8 µm VS 12.3 µm respectively). This put the screw on the verge of loosening in screw retained restoration, while the cement retained restoration remained stable [Figures 8 and 9].

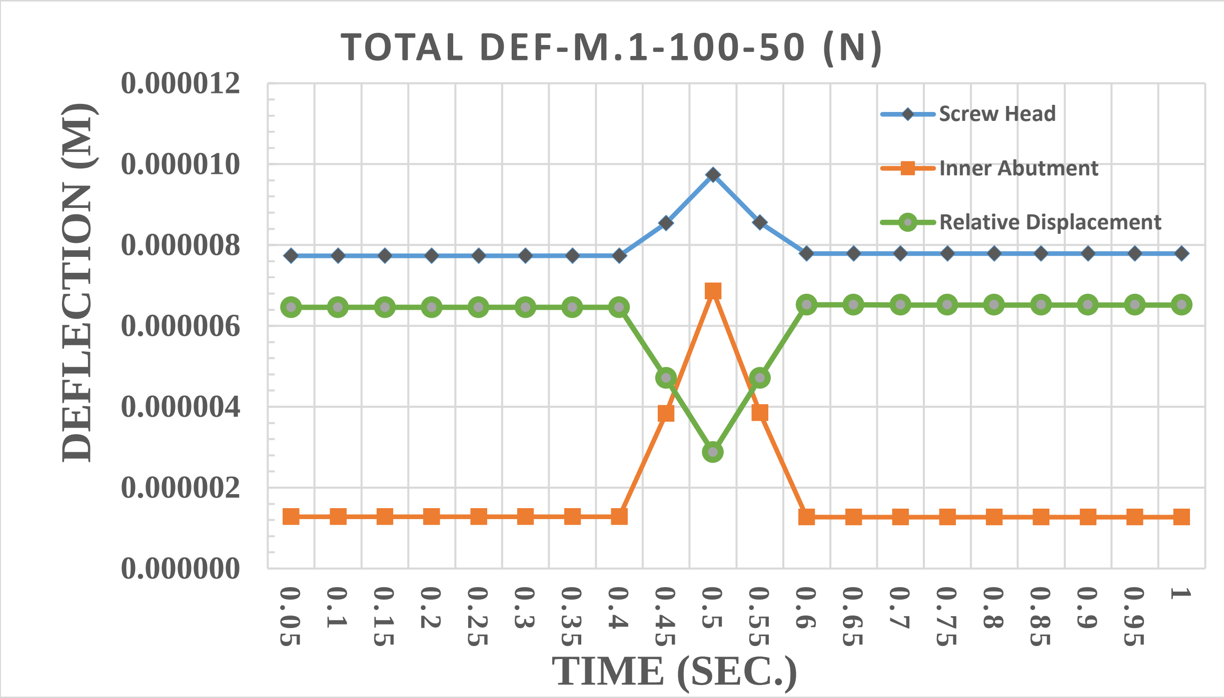

FIGURE 8 The amount of displacement at the head of screw and inner side of abutment in cement retained restoration by applying concomitant vertical (100 N) and horizontal (50 N) load

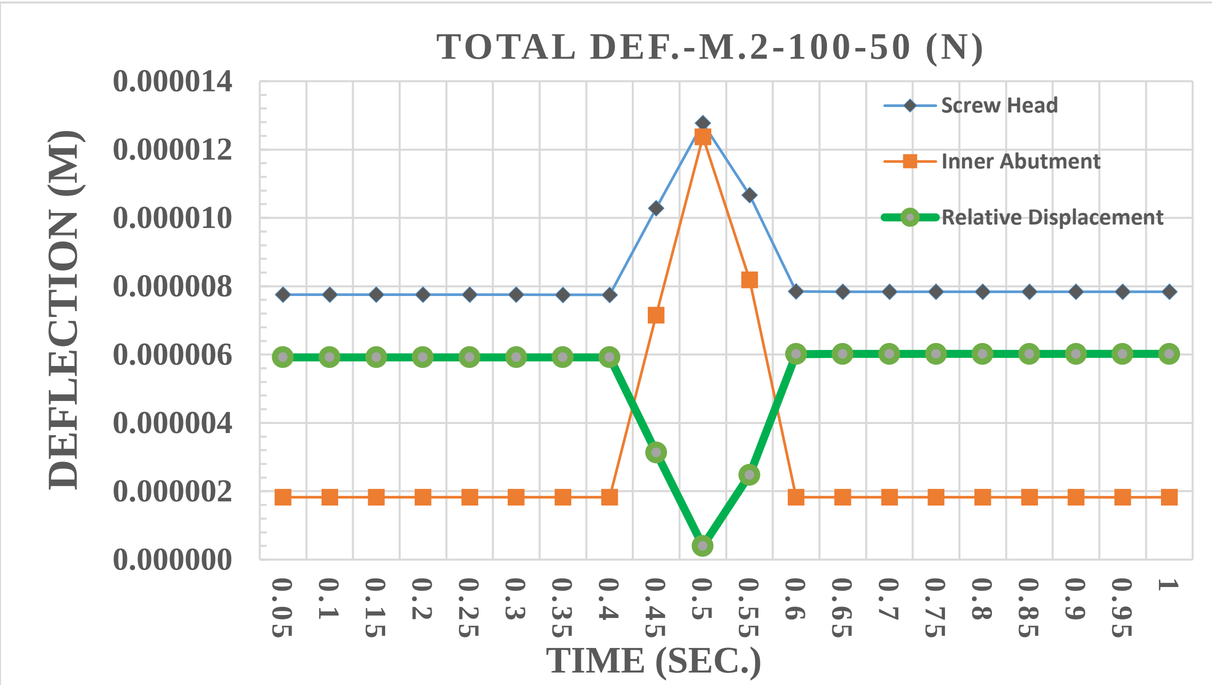

FIGURE 9 The amount of displacement at the head of screw and inner side of abutment in screw retained restoration by applying concomitant vertical (100 N) and horizontal (50 N) load. The little difference in displacement between the head of screw and inner side of abutment made the abutment-implant complex unstable.

Displacement analysis by applying oblique load of 100 N

By applying oblique load of 100 N the amount of displacement in screw retained restoration at both inner side of abutment and the head of screw was significantly greater than that of cement retained restoration. In screw retained restoration, displacement at the inner side of abutment exceeded the head of the screw displacement (14.6µm VS 14µm respectively). In this circumstance, the implant-abutment complex in screw retained restoration became unstable and head of screw loosened [Figures 10 and 11].

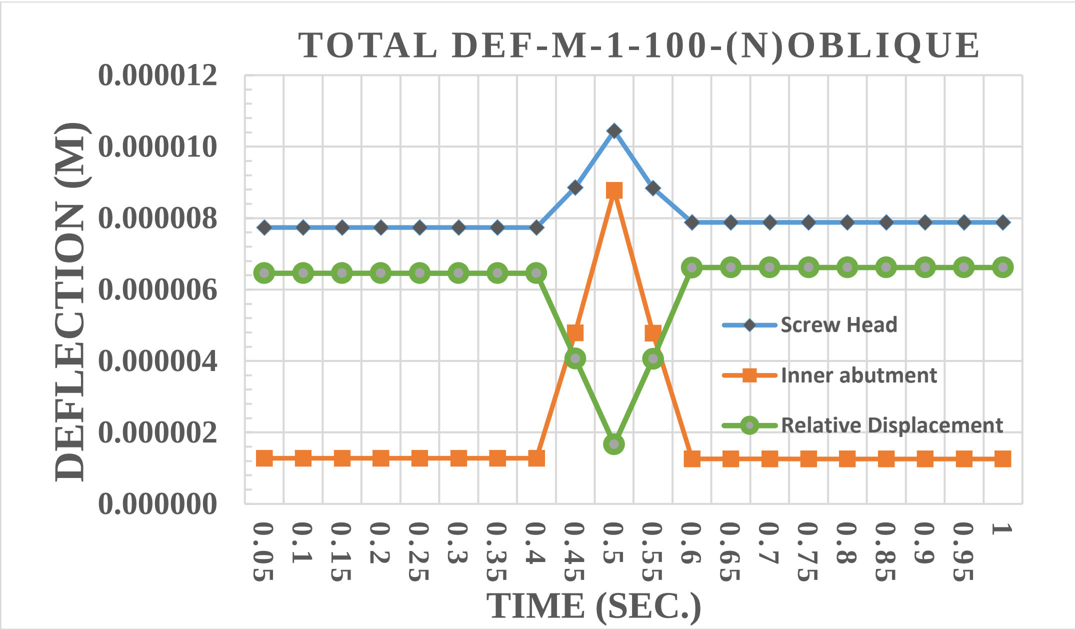

FIGURE 10 The amount of displacement at the head of screw and inner side of abutment in cement retained restoration by applying oblique (45°) load of 100 N.

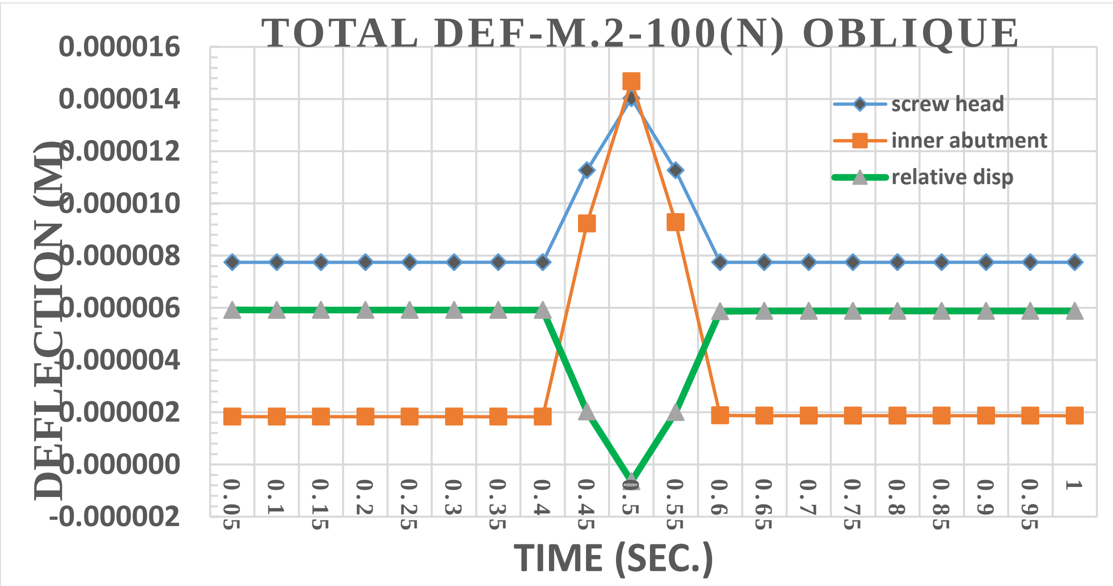

FIGURE 11 The amount of displacement at the head of screw and inner side of abutment by applying oblique (45°) load of 100 N. As shown in this figure, the inner side of abutment displacement was greater than the head of screw displacement, so the implant-abutment complex became unstable and the screw loosened.

Discussion

As a result of the continued high rate of success achieved with osseous integrated dental implants, a greater number of patients can enjoy the benefits of fixed dental prostheses, as opposed to removable prostheses [25]. Nevertheless, long-term follow-up studies on implants reported that many problems arise after the prosthetic phase. These problems are loss of osseointegration [26], abutment screw loosening [27], abutment screw fracture [28] and so on [29,30]. Many clinical studies mentioned abutment screw loosening as a recurrent problem associated with single-tooth implants [31-37]. Some articles report higher prevalence of screw loosening in screw-retained restoration [15,16,17] while others in cement-retained restoration [11]. Therefore, this study intended to make a comparison between cement retained and screw retained implant supported crowns, using a dynamic non-Linear Finite Element Analysis.

A finite element analysis (FEA) represent advantages versus the experimental methods as it enables the handling of more complex settings, and supply a greater insight into detailed results about the internal stress of both tooth and restorations [38].

In this study, screw loosening was investigated by comparing the displacement of head screw and inner surface of abutment between screw retained and cement retained restoration. This survey was done by applying 4 types of forces and using FEM.

In cement retained restoration, the amount of relative displacement between head of screw and inner surface of abutment by applying preload 400 N(0-0.4 s and 0.6-1 s) was the most [Figure 12].Thus, applying 400 N as the preload provides the least possibility for screw loosening. By applying vertical or oblique forces (0.4–0.6 s) relative displacement reduced in all types of loading which reveals that vertical or oblique forces lead to neutralize a part of preload displacement and turn the screw toward loosening. According to Figure 12 relative displacement from maximum to minimum has occurred by 100 N vertiacl,150 N vertical,100 N vertical + 50 N horizontal, 100 N oblique (45 degree). In other word, by applying more quantity of force and presence of non-vertical load, the possibility of screw loosening has increased. However, none of the loading models in cement retained restoration experienced screw loosening.

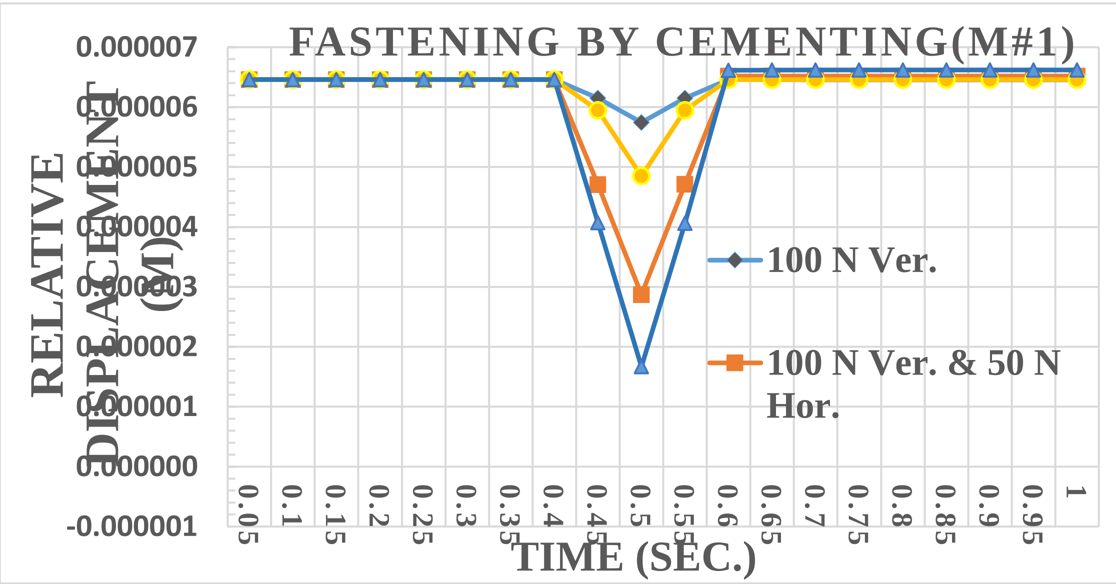

FIGURE 12 Relative displacement in cement retained restoration by applying four types of loading

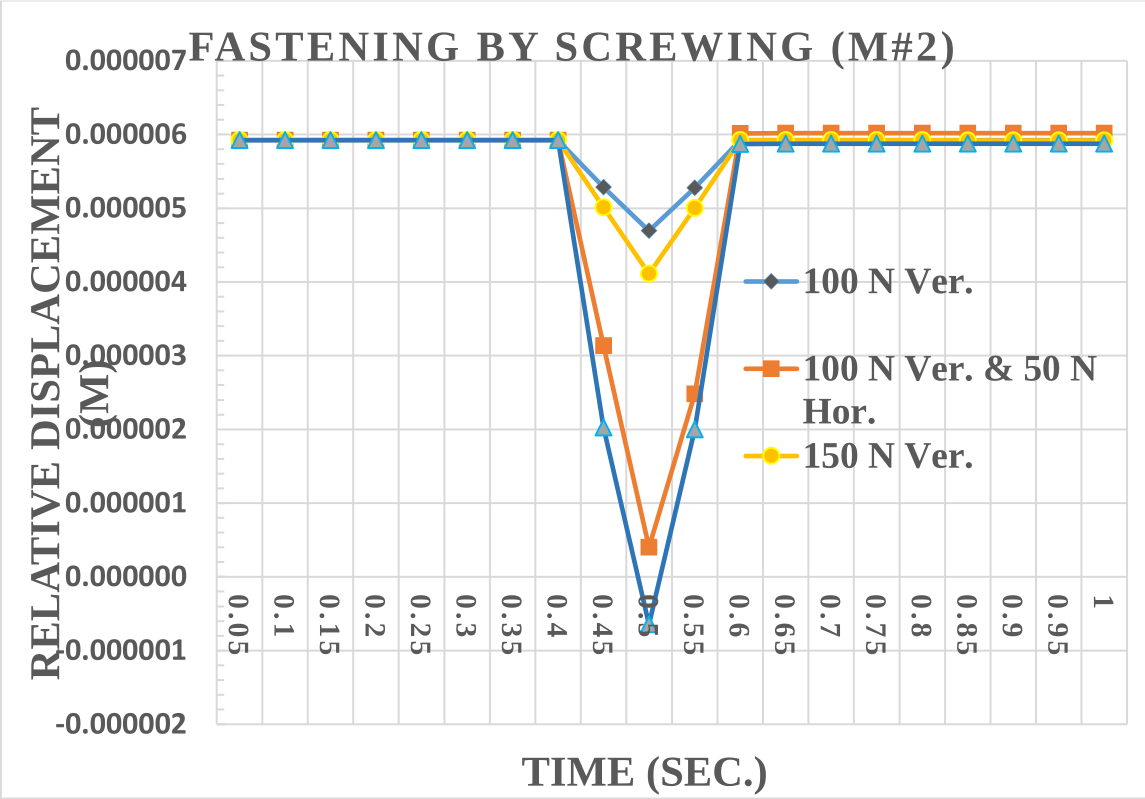

FIGURE 13 Relative displacements in screw retained restoration by applying 4 types of forces

In screw retained restoration, relative displacement occurred in same arrange with cement retained restoration. However, as shown in Figure 13, the amount of relative displacement in all types of loading is less than cement retained restoration and the difference in relative displacement between screw retained and cement retained restoration increased by applying non vertical forces, so that by applying 100 N vertical +50 N horizontal, the head of screw was on the verge of loosening and by applying 100 N oblique, inner surface of abutment moved 0.6 µm more than head of screw which led to loosening of screw.

The result of present study confirmed better performance of cement retained restoration that have reported in other studies and clarified more problems in screw retained restoration [16,17,39,40].

The results of this study are in line with that of Silva et al. [20]. They reported that biomechanical problems in screw retained restoration is more than that of cement retained restoration. However, in their study 3-unit prosthesis was investigated and material of suprastructures for both prosthesis was the same (gold alloy). They exclusively investigated the pattern of stress distribution and did not consider screw loosening while in present study single unit prostheses which have the most possibility for screw loosening were investigated and the material of suprastructures was not the same for restorations because for the suprastructures of screw retained and cement retained restoration CCM alloy+Ni-Cr alloy, Ni-Cr alloy were used, respectively. Also, in this study, four types of loading were evaluated while study of Silva et al was done by two types of forces.

Some factors can explain more possibility of screw loosening in screw retained restoration. Differences in modulus of elasticity is one of these factors. Since the shape of outer surface of restorations are the same, the only influential factor is modulus of elasticity of components. There are obvious differences in Material characteristics especially modulus of elasticity in models evaluated in this study. Cement retained restoration is stiffer than that of screw retained restoration. There is a screw access hole in suprastructure of screw retained restoration. This hole is filled with composite resin in clinical situation that has far less modulus of elasticity than the material in same position in suprastructure of cement retained restoration (7Gpa VS 150 Gpa). This parameter may cause differences in displacement between the two restorations.

Despite the higher risk of mechanical problems mentioned in the literature and in this study, the screw retained restoration is a trustworthy treatment [12,16,39,41,42,43,44,45]. Screw retained restoration represents some biological advantages compared with the cement retained prosthesis [16]. However, when a clinician selects screw retained restoration, he should pay attention to factors that can reduce the loads and stresses over the prosthetic complex. These advantageous factors are precise occlusal adjustment, passive fit of frame work and proper torque on the screw. Certainly, these factors also should be considered about cement retained prosthesis.

Conclusion

Screw loosening is less likely to occur under vertical load compared with oblique load. The cemented retained restorations have higher biomechanical stability than screw retained restorations.

Conflict of interest statement: The authors declare that they have no conflicts of interest.

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