AN IN VITRO EVALUATION AND COMPARISON OF PERI-IMPLANT STRAIN GENERATED IN CEMENT RETAINED AND SCREW RETAINED PROSTHESES FABRICATED USING THREE DIFFERENT PROSTHETIC MATERIAL

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Abstract:
Context: peri-implant strain, cement and screw retained implant Prostheses
Aims: To compare peri implant strain generated in implant supported prostheses, cement retained and screw retained, with three different materials, all metal vs porcelain fused to metal vs all ceramic using invitro testing system.
Settings and Design: A total of 60 samples of implant supported prostheses were made. 30 for cement retained (10 for all metal, 10 for porcelain fused to metal, 10 for All ceramic) and 30 for screw retained (10 for all metal,10 for porcelain fused to metal,10 for All ceramic)
Methods and Material: In a PMMA mandibular model a dummy implant (ADIN), was placed on the right and left side of the region. Simultaneous static load application at central fossae region of both the crowns was administered, of 400 N on each prostheses for a period of 10 seconds using universal testing machine, and peri-implant strains was measured with digital image correlation method.
Statistical analysis used: Data were summarised as Mean ± SE. Groups were compared together by two factors (groups x subgroups) ANOVA and the significance of mean difference within (intra) and between (inter) the groups was done by Tukey's HSD post hoc test. Analyses were performed on SPSS software.
Results: Here mean peri implant strain (±SD) generated was found to be highest in All ceramic screw retained implant prosthesis and least in All metal cement retained implant prosthesis respectively.
Conclusions: Here we concluded that the Implant design, superstructure material, and load direction significantly affect peri-implant microstrains.

Key-words: peri implant strain, implant supported prostheses, cement retained, screw retained
Key Messages: Within the limitations of this study to replicate osseointegration, occlusal forces and modulus of elasticity of mandibular bone the results suggest that the Implant design, superstructure material, and load direction significantly affect peri-implant microstrains.

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INTRODUCTION

The use of endosseous implants has achieved success rates that are generally greater than 95%,[1] Implant supported prostheses have achieved popularity and also have become the standard of care. A lot of optimization has happened in the selection of materials, design and the related techniques. Clinical implant prosthodontics presently focuses on the prognostification of cemented and screw retained crowns[2].

While selecting the type of prostheses for a given clinical situation, along with the esthetics and function, peri implant strain generated in the surrounding bone should also be considered to ensure the long term success of the prostheses.[3]

The criteria for minimum peri-implant strain is one of long term survival of any implant prostheses. Peri-implant strain more than 4000 micro strain leads to pathologic fracture of the bone.[4] Therefore, occlusal overload is a primary factor for generation of peri implant strain, peri implant bone loss as well as loss of implant supported prostheses.[5] Transfer of occlusal load is related to several factors such as type of prostheses and the type of retention. Implant-supported restorations can be secured to implants with screws (screw-retained), or they can be cemented to abutments which are attached to implants (cement-retained)[6].

There was limited literature available regarding the influence of different restorative materials on the peri-implant strain generated. Hence, this study was undertaken to compare the peri-implant strain generated in cement retained and screw retained implant prostheses fabricated using three different prosthetic materials(all metal, porcelain fused to metal, All ceramic)using digital image correlation technique.

SUBJECT AND METHOD

The present study was conducted in Department of Prosthodontics Crown and Bridge and Implantology at Sardar Patel Post Graduate Institute of Dental and Medical Sciences, Lucknow in collaboration with the branch of Mechanical Engineering Indian Institute of Technology, Kanpur Uttar Pradesh.

Here a total of sixty samples of implant supported prostheses were made which were further divided in 2 different groups, Thirty for cement retained(Ten for all metal, Ten for porcelain fused to metal, Ten for All ceramic) and Thirty for screw retained(Ten for all metal, Ten for porcelain fused to metal, Ten for All ceramic)

Ethical Clearance was taken with the no. from the institution.

All the samples was examined using Universal Testing Machine and analysed with Digital Image Correlation system.

Sample Preparartion for Cement Retained Prostheses on Polymethylmetha acrylate mandibular Model.

In a PMMA mandibular model ((Plexiglas®, Altuglas International, PA, USA) Figure2 a dummy implant (ADIN), wide (3.75D × 10L) was placed on the left side of the region (36). First molar region was selected for implant placement as maximum occlusal forces act on the posterior part of the ridge and therefore maximum peri implant strain is generated in that region of the arch.

For the fabrication of cement retained prostheses, a closed tray impression technique was used to make impression and was poured in die stone. Cement retained prostheses was made on prefabricated abutment using three different prosthetic material i.e All metal, Porcelain fused to metal, All ceramic. Thirty cement retained prostheses were made.Ten samples in each group using different prosthetic material.

Sample Preparartion for Screw Retained Prostheses on Polymethylmethacrylate dentulous Mandibular Model.

In a PMMA mandibular model ((Plexiglas®, Altuglas International, PA, USA)) a dummy implant (ADIN), wide (3.75D × 10L) was placed on the right side of the region(46)Figure3.For the fabrication of screw retained implant prostheses impression coping was placed on the dummy implant and a closed tray impression technique used Figure 5,6.Impression was poured in die stone.

Screw retained prostheses were made using custom abutments using three different prosthetic materials i.e All metal, Porcelain fused to metal, All ceramic. Abutments were screw tightened at the torque of 25Ncm.Thirty screw retained prostheses were made with ten samples in each group using different prosthetic material.

On the model all three different implant prostheses were placed at the position of first molar on cement retained prostheses and screw retained prostheses simultaneously on both the quadrants (36,46) and the readings were taken individually. The cement retained prostheses were luted with zinc phosphate cement.

For determing the peri implant strain digital image correlation were done. It is reported that Digital Image Correlation method can provide measurements with subpixel accuracy, in the order of 0.08 pixels[7]

A metal jig was fabricated to ensure simultaneous load application at central fossae region of both the crowns. The Jig was attached to the universal testing machine. A static load of 400 N was applied on each prostheses for a period of 10 seconds using universal testing machine. The load of 400N was selected because in healthy, dentulous subjects, the total occlusal force in the molar region at maximum clenching strength was reported to be 400N.Load were applied ten times on each sample simultaneously and peri-implant strains will be measured with digital image correlation method.

Statistical analysis

Data were summarised as Mean ± SE (standard error of the mean). Groups were compared together by two factor (groups x subgroups) analysis of variance (ANOVA) and the significance of mean difference within (intra) and between (inter) the groups was done by Tukey's HSD (honestly significant difference) post hoc test after ascertaining normality by Shapiro-Wilk's test and homogeneity of variance between groups by Levene's test. Groups were also compared by Student's t test. A two-tailed (α=2) p<0.05 was considered statistically significant. Analyses were performed on SPSS software (Windows version 17.0).

Results and Observations

The outcome measure of the study was per-implant strain measured in microstrain. The objective of the study was to compare the peri-implant strain within the groups (i.e. intra groups) and between the groups (i.e. inter groups).

Peri-implant strain

A. Intra group

I. Group I

The peri-implant strain of three subgroups of Group I (Group IA, Group IB and Group IC) are summarised in Table 5 and also depicted in Fig. 22. In Group I, the peri-implant strain of subgroups Group IA, Group IB and Group IC ranged from 590.3-767.5, 742.2-927.7 and 697.2-1127.2 microstrain respectively with mean (± SE) 716.30 ± 18.54, 829.77 ± 23.99 and 895.25 ± 54.53 microstrain respectively and median 739, 845 and 906 microstrain respectively. In Group I, the mean peri-implant strain of subgroup Group IC was the maximum followed by Group IB and Group IA the minimum (Group IA < Group IB < Group IC) (Table 5 and Fig. 22).

In Group I, comparing the difference in mean peri-implant strain between the subgroups, Tukey test showed significantly different and higher (19.99%) peri-implant strain in subgroup Group IC as compared to subgroup Group IA (716.30 ± 18.54 vs. 895.25 ± 54.53, mean diff=178.95, p=0.014) (Table 6 and Fig. 23). However, it did not differ (p>0.05) between subgroups Group IA and Group IB (716.30 ± 18.54 vs. 829.77 ± 23.99, mean diff=113.47, p=0.267), and subgroups Group IB and Group IC (829.77 ± 23.99 vs. 895.25 ± 54.53, mean diff=65.48, p=0.808) though it was found 13.67% higher in subgroup Group IB as compared to subgroup Group IA, and 7.31% higher in subgroup Group IC as compared to subgroup Group IB.

II. Group II

The peri-implant strain of three subgroups of Group II (Group IIA, Group IIB and Group IIC) are summarised in Table 7 and also shown in Fig.24. In Group II, the peri-implant strain of subgroups Group IIA, Group IIB and Group IIC ranged from 647.3-820.6, 670.2-989.1 and 711.5-1130.1 microstrain respectively with mean (± SE) 737.93 ± 21.50, 854.98 ± 34.81 and 922.45 ± 51.13 microstrain respectively and median 734, 893 and 911 microstrain respectively. Like, Group I, in Group II, the mean peri-implant strain of subgroup Group IIC was the maximum followed by Group IIB and Group IIA the minimum (Group IIA < Group IIB < Group IIC) (Table 7and Fig. 24).

In Group II, comparing the difference in mean peri-implant strain between the subgroups, Tukey test showed significantly different and higher (20.00%) peri-implant strain in subgroup Group IIC as compared to subgroup Group IIA (737.93 ± 21.50 vs. 922.45 ± 51.13, mean diff=184.52, p=0.011) (Table 8 and Fig. 25). However, it did not differ between subgroups Group IIA and Group IIB (737.93 ± 21.50 vs. 854.98 ± 34.81, mean diff=117.05, p=0.236), and subgroups Group IIB and Group IIC (854.98 ± 34.81 vs. 922.45 ± 51.13, mean diff=67.47, p=0.788) though it was found 13.69% higher in subgroup Group IIB as compared to subgroup Group IIA, and 7.31% higher in subgroup Group IIC as compared to subgroup Group IIB.

B. Inter group

I. Group IA vs. Group IIA

The peri-implant strain of two subgroups of Group I and Group II (Group IA and Group IIA) are further summarised in Table 9. The mean peri-implant strain of subgroup Group IIA was slightly higher than subgroup Group IA (Group IA < Group IIA) (Table 9 and Fig. 26).

Comparing the difference in mean peri-implant strain between two subgroups, Tukey test showed similar (p>0.05) peri-implant strain between the two subgroups Group IA and Group IIA (716.30 ± 18.54 vs. 737.93 ± 21.50, mean diff=21.63, p=0.998) though it was 2.93% higher in subgroup Group IIA as compared to subgroup Group IA (Table 9 and Fig. 27).

II. Group IB vs. Group IIB

The peri-implant strain of two subgroups of Group I and Group II (Group IB and Group IIB) are further summarised in Table 10. The mean peri-implant strain of subgroup Group IIB was slightly higher than subgroup Group IB (Group IB < Group IIB) (Table 10 and Fig. 28).

Comparing the difference in mean peri-implant strain between two subgroups, Tukey test showed similar (p>0.05) peri-implant strain between the two subgroups Group IB and Group IIB (829.77 ± 23.99 vs. 854.98 ± 34.81, mean diff=25.21, p=0.997) though it was 2.95% higher in subgroup Group IIB as compared to subgroup Group IB (Table 10 and Fig. 29).

III. Group IC vs. Group IIC

The peri-implant strain of two subgroups of Group I and Group II (Group IC and Group IIC) are further summarised in Table 11. The mean peri-implant strain of subgroup Group IIC was slightly higher than subgroup Group IC (Group IC < Group IIC) (Table 11 and Fig. 30).

Comparing the difference in mean peri-implant strain between two subgroups, Tukey test showed similar (p>0.05) peri-implant strain between the two subgroups Group IC and Group IIC (895.25 ± 54.53 vs. 922.45 ± 51.13, mean diff=27.20, p=0.995) though it was 2.95% higher in subgroup Group IIC as compared to subgroup Group IC (Table 11 and Fig. 31).

IV. Group I vs. Group II

To find the efficacy of one group over other groups, the total peri-implant strain of two groups (Group I and Group II) were evaluated and summarised in Table 12 and also depicted in Fig. 32. The total peri-implant strain of Group I and Group II ranged from 2062.8-2758.5 and 2040.7-2889.5 microstrain respectively with mean (± SE) 2441.32 ± 82.32 and 2515.36 ± 92.78 microstrain respectively and median 2546 and 2627 microstarin respectively. The mean total peri-implant strain of Group II was comparatively higher than Group I (Group I < Group II) (Table 12 and Fig. 32).

Comparing the difference in mean total peri-implant strain of two groups, Student's t test showed similar (p>0.05) total peri-implant strain between the two groups (2441.32 ± 82.32 vs. 2515.36 ± 92.78, mean diff=74.04, p=0.558) though it was 2.94% higher in Group II as compared to Group I (Table 12 and Fig. 33).

TABLES

Peri-implant strain

A. Intra group

I. Group I

Table 5: Peri-implant strain (microstrain) of three subgroups of Group I

Group I	N	Range (min-max)	Mean ± SE	Median
Group IA	10	590.3-767.5	716.30 ± 18.54	739
Group IB	10	742.2-927.7	829.77 ± 23.99	845
Group IC	10	697.2-1127.2	895.25 ± 54.53	906

Table 6: Comparison of difference in mean peri-implant strain between subgroups of Group I by Tukey test

Comparison	Mean difference (microstrain)	Mean difference (%)	p value
Group IA vs. Group IB	113.47	13.67	0.267
Group IA vs. Group IC	178.95	19.99	0.014
Group IB vs. Group IC	65.48	7.31	0.808

II. Group II

Table 7: Peri-implant strain (microstrain) of three subgroups of Group II

Group II	n	Range (min-max)	Mean ± SE	Median
Group IIA	10	647.3-820.6	737.93 ± 21.50	734
Group IIB	10	670.2-989.1	854.98 ± 34.81	893
Group IIC	10	711.5-1130.1	922.45 ± 51.13	911

Table 8: Comparison of difference in mean peri-implant strain between subgroups of Group II by Tukey test

Comparison	Mean difference (microstrain)	Mean difference (%)	p value
Group IIA vs. Group IIB	117.05	13.69	0.236
Group IIA vs. Group IIC	184.52	20.00	0.011
Group IIB vs. Group IIC	67.47	7.31	0.788

B. Inter group

I. Group IA vs. Group IIA

Table 9: Peri-implant strain (microstrain) of two subgroups of Group I and Group II

Subgroup	n	Mean ± SE	Mean difference	Mean difference (%)	p value
Group IA	10	716.30 ± 18.54	21.63	2.93	0.998
Group IIA	10	737.93 ± 21.50			

II. Group IB vs. Group IIB

Table 10: Peri-implant strain (microstrain) of two subgroups of Group I and Group II

Subgroup	n	Mean ± SE	Mean difference	Mean difference (%)	p value
Group IB	10	829.77 ± 23.99	25.21	2.95	0.997
Group IIB	10	854.98 ± 34.81			

III. Group IC vs. Group IIC

Table 11: Peri-implant strain (microstrain) of two subgroups of Group I and Group II

Subgroup	n	Mean ± SE	Mean difference	Mean difference (%)	p value
Group IC	10	895.25 ± 54.53	27.20	2.95	0.995
Group IIC	10	922.45 ± 51.13			

IV. Group I vs. Group II

Table 12: Total peri-implant strain (microstrain) of two groups

Group	N	Mean ± SE	Mean difference (%)	t value	p value
Group I	10	2441.32 ± 82.32	74.04 (2.94)	2.95	0.995
Group II	10	2515.36 ± 92.78			

- As per the analysis of the obtained results the following inference was drawn

Peri implant strain was highest in Screw retained Group IIC (all ceramic)>Group IIB(porcelain fused to metal)>Group IIA(all metal)>cement retained Group IC (all ceramic)>Group IB(Porcelain fused to metal)>Group IA(all metal)

DISCUSSION

The present study depicts the mean peri implant strain (±SD) generated was found to be highest in All ceramic screw retained implant prosthesis 922.45 ± 51.13 microstrain respectively and least in All metal cement retained implant prosthesis 716.30 ± 18.54 respectively. Screw retained implant prostheses show the highest mean peri implant strain than cement retained implant prostheses 2515.36 ± 92.78 vs 2441.32 ± 82.32.

The result of the present study matches with that of the *in vitro* study conducted by Lamiaa Sayed Elfadaly et al[8] (2017)evaluated that mean peri implant strain was highest in all ceramic than all metal prosthetic crown. There was another study that concided with the result of an invitro study conducted by I Rani et al[8] (2017) evaluated that the mean peri implant strain is highest in non-splinted screw retained prosthesis and least in non-splinted cement retained prosthesis._ Koller *et al*[9]*(2016)* evaluated retrospectively the association among occlusal, periodontal and implant-prosthetic parameters and marginal bone loss (MBL) around implants after prosthetic loading. Regarding implant-prosthetic parameters, statistically significant differences were observed for cemented versus screwed, and single versus splinted crowns, with grater MBL observed for splinted and cemented prostheses. Inadequate occlusal pattern guide, presence of visible plaque, and cemented and splinted implant-supported restoration were associated with greater Marginal bone loss around the implant.

An systematic review on cementation Vs screw retention presented in 2012 by European Association Of Osseointegration[10], focused on implant and reconstructive survival, and calculated the estimated 5-year and 10-year technical and biological complication rates obtained from studies with a mean follow-up of at least 1 year. The event rates were grouped for either cement retained or screw retained single crowns, FPDs and full-arch FPDs. No statistically significant differences were reported in the survival of screw retained and cement retained FDPs. Biological complication rates (bone loss > 2 mm) were found to be higher for cemented prostheses, whereas screw retained FDP exhibited more technical complications .The authors concluded that screw retained FDPs should be given preference due to their greater retrievability[10] In another systematic review, performed by Weber& Sukotjo[11] the success rates of screw retained and cement retained implant-supported FDPs after the last reported examination (> 72 months) were 93.2% for cement and 83.4% for screw. There were more complications with screw retention, but this was statistically not significant

Limitations of the present model must be taken into account when interpreting the results of this investigation.

This is an *in vitro* study based on a homogenous model with known mechanical properties instead of bone, which allowed not only proper strain measurements, but also 100% implant-model material contact. *In vivo*, additional variables like bone density, implant stability, and bone-to-implant contact would have to be considered.[5]

Different implant design (mini implant, short wide implant, standard implant)[8] and abutment selection (angulated, straight) changes the peri implant strain.

The occlusal design of the superstructures could change the results of the study variables such as cusp inclination, occlusal table and location, direction and magnitude of applied occlusal forces. In addition, in this study, implants were loaded in a vertical inclination, while in the clinical setup[12], nonaxial loads are also generated which will influence the peri implant strain.

Role of cement between the abutment and the crown in cement retained prosthesis may be a limiting factor in peri implant strain and must further be investigated.

Future Leads

- Vertical occlusal loads were used in this study. These tend to produce more favourable strain distributions within both the prosthesis and the surrounding bone. The more challenging oblique loading is expected to lead to higher strain values in the system and even greater differences between the different prosthetic material which could be evaluated in further studies.[13]
- Further studies are to be carried out measuring peri implant strain in screw cement retained implant prosthesis.
- Studies should be conducted on measuring peri implant strain in different implant designs such as wide implant ,angulated implant

CONCLUSION:

- Within the limitations of this study to replicate osseointegration, occlusal forces and modulus of elasticity of mandibular bone the results suggest that the Implant design, superstructure material, and load direction significantly affect peri-implant microstrains.
- The recorded compressive and tensile microstrains for the tested designs were within the physiologic loading range, as they did not exceed the compressive or tensile strength of the bone-implant interface, which is more than 4000 microstrains.
- Peri implant strain more than 4000 microstrains results in deformation of bone surrounding the implant.
- Peri implant strain in cement retained all metal was less than the screw retained all metal prosthesis.
- Peri implant strain in cement retained porcelain fused to metal was less than the porcelain fused to metal in screw retained prosthesis.
- Peri implant strain in cement retained all ceramic was less than the screw retained all ceramic prosthetic material.
- Peri implant strain in cement retained implant prosthesis was less than the screw retained implant prosthesis.
- Peri implant strain in poly methyl methacrylate model using digital image correlation technique was highest in screw retained prosthesis followed by screw retained all ceramic superstructure, followed by screw retained porcelain fused to metal super structure followed by all metal superstructure and peri implant strain was less in cement retained prosthesis followed by all metal super structure, followed by porcelain fused to metal super

structure followed by all ceramic superstructure. Group II C(all ceramic)>Group IIB(porcelain fused to metal)>Group II A(all metal)>cement retained Group IC (all ceramic)>Group IB(Porcelain fused to metal)>Group IA(all metal).

- Effect of luting agent on peri implant strain was not investigated in this study.
- The intraoral conditions could not be simulated while testing of samples such as repeated rhythmic loading of the prosthesis under masticatory loads, which leads to fatigue of the prosthesis and causes fracture, and also, the lateral forces were not taken into consideration
- Clinical trials along with also, other properties like color stability, microhardness, modulus of elasticity, location of screw access hole, marginal adaptability, bucco lingual diameter need to be further investigated to help the clinician in selecting the most optimum prosthetic material for clinical use.

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