Original Article

Effect of joining the sectioned implant-supported prosthesis on the peri-implant strain generated in simulated mandibular model

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Abstract

Aim: The aim of this study is to evaluate the strain developed in simulated mandibular model before and after the joining of an implant-supported screw-retained prosthesis by different joining techniques, namely, arc welding, laser welding, and soldering.

Materials and Methods: A specimen simulating a mandibular edentulous ridge was fabricated in heat-cured acrylic resin. 4-mm holes were drilled in the following tooth positions; 36, 33, 43, 46. Implant analogs were placed in the holes. University of California, Los Angeles, abutment was attached to the implant fixture. Eight strain gauges were attached to the acrylic resin model. Six similar models were made. Implant-supported screw-retained fixed prosthesis was fabricated in nickel-chromium alloy. A load of 400 N was applied on the prosthesis using universal testing machine. Resultant strain was measured in each strain gauge. All the prostheses were sectioned at the area between 36 and 33, 33 and 43, and 43 and 46 using 35 micrometer carborundum disc, and strain was measured in each strain gauge after applying a load of 400 N on the prosthesis. Specimens were joined by arc welding, soldering, and laser welding. After joining, a load of 400 N was applied on each prosthesis and the resultant strain was measured in each strain gauge.

Results: Highest mean strain values were recorded before sectioning of the prostheses (889.9 microstrains). Lowest mean strain values were recorded after sectioning the prosthesis and before reuniting it (225.0 microstrains).

Conclusions: Sectioning and reuniting the long-span implant prosthesis was found to be a significant factor in influencing the peri-implant strain.

Keywords: Arc welding, laser welding, passive fit, peri-implant strain, soldering

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INTRODUCTION

A precise fit between an implant body and an abutment as well as between an implant abutment and superstructure are important factors in determining the long-term success of an implant-supported prosthesis. Thus, when the fit is not satisfactory, tensile, compressive, and torsional stresses may be introduced into the prosthesis.[1] This

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may result in loss of osseointegration, loosening of the prosthesis or abutment screws, distortion or breakage of prosthesis, microfractures in the bone surrounding the implant, or fracture of implant body.[1] Watanabe *et al.* proposed that 90% of the contact surfaces between an abutment and its superstructure will have a gap within the range of 30-micron meter, which is too small to be clinically detectable.[2] Therefore, the cast framework that seems to fit well upon visual examination could undergo distortion or deformation of the contacting surface during the tightening of the prosthesis as well as induce stresses on the bone surrounding the implant.[3] Obtaining passive fit in a long-span prosthesis is a challenge, and various methods have been developed to improve the fit between abutment and its superstructure such as sectioning and joining method (one-piece cast superstructure is cut into pieces corresponding to each abutment and then pieces are reassembled and joined) and use of IMZ "passive-fit system" (utilizes fastening screws, sleeves, plastic sleeves, and titanium coping).[4] The objective of this study was to investigate the strain produced in the bone surrounding implants when the long-span implant-supported prostheses were fabricated using one-piece casting method and to compare it with the strain generated when prostheses were sectioned and reunited by various techniques, namely, soldering, arc welding, and laser welding. The hypothesis of the study was that there is no difference between the peri-implant strain generated on the bone before and after sectioning and joining the long-span implant-supported prosthesis irrespective of the joining technique used.

MATERIALS AND METHODS

Preparation of the specimen

Specimen consisting of a 10-mm thick flat base and a rim simulating a mandibular edentulous ridge was fabricated in modeling wax [Figure 1]. This was duplicated in heat-cured acrylic resin. 4-mm holes were drilled in the following tooth positions; 36, 33, 43, 46 using tungsten carbide bur (4 mm diameter). Make it simple, implant analogs of dimension 3.75 mm × 11.5 mm were placed in the holes and they were secured in place with autopolymerizing acrylic resin [Figure 2]. University of California, Los Angeles (UCLA) abutment was attached to the implant fixture. All the abutments were fixed to the implant with a torque of 35 Ncm using torque wrench. Implant-supported screw-retained fixed prosthesis framework was fabricated in nickel-chromium alloy connecting all the four implant analogs [Figures 3 and 4]. All the prostheses were fixed to the abutment with a torque of 35 Ncm using a torque wrench.

Figure 1: Wax for of simulated mandibular model

Figure 2: Heat-cured acrylic model with implants

Figure 3: Screw-retained implant-supported prosthesis

Eight strain gauges (resistance 350 ohms, length 3 mm, factor 2.01) were attached to the acrylic model mesial and distal to the implants [Figure 5]. All the strain gauges were set to zero. Strain gauges were numbered according to their position next to the implant. Six similar models were made.

1. Strain gauge fixed distal to the right first molar implant (46)
2. Strain gauge fixed mesial to the right first molar implant (46)
3. Strain gauge fixed distal to the right canine implant (43)
4. Strain gauge fixed mesial to the right canine implant (43)
5. Strain gauge fixed mesial to the left canine implant (33)
6. Strain gauge fixed distal to the left canine implant (33)
7. Strain gauge fixed mesial to the left first molar implant (36)
8. Strain gauge fixed distal to the left first molar implant (36).

Grouping specimens

Six specimens were grouped into three - A, B, C with each group consisting of two specimens, according to the joining methods used, i.e., soldering, arc welding, laser welding.

Measurement of the strain

A load of 400 N was applied for a period of 10 s on the prosthesis using universal testing machine. A steel plate of 50 mm diameter was used to ensure uniform contact of the prosthesis during load application. Resultant strain was recorded with respect to each strain gauge.

Sectioning of the prosthesis

All the prosthesis were sectioned between 36 and 33, 33 and 43, and 43 and 46 [Figure 6] using 35 micrometer carborundum disc, and strain was measured in each strain gauge after applying a load of 400 N on the sectioned prosthesis for 10 s.

Joining of the prosthesis

Sectioned specimens of groups A, B, and C were united by arc welding, soldering, and laser welding, respectively. After joining, a load of 400 N was applied on each prosthesis for a period of 10 s and the resultant strain was recorded in each strain gauge [Figure 7].

RESULTS

Results of the present study are given in the following tables. Table 1 consists of the peri-implant strain values before sectioning of the prostheses. Table 2 consists of the strain values after sectioning of the prostheses. Tables 3-5 consists of the strain values after joining of the sectioned prostheses by arc welding, soldering, and laser welding, respectively. Table 6-10 contains mean and standard deviation before sectioning, after sectioning, after arc welding, after soldering and after laser welding the prostheses respectively.

Statistical analysis

The statistical analysis was performed using the one-way analysis of variance (ANOVA) and Scheffe's *post hoc* test.

Figure 4: Mandibular model with the prosthesis

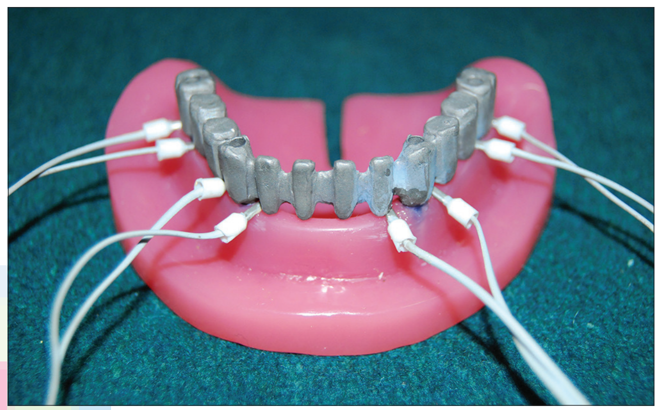

Figure 5: Model with strain gauges

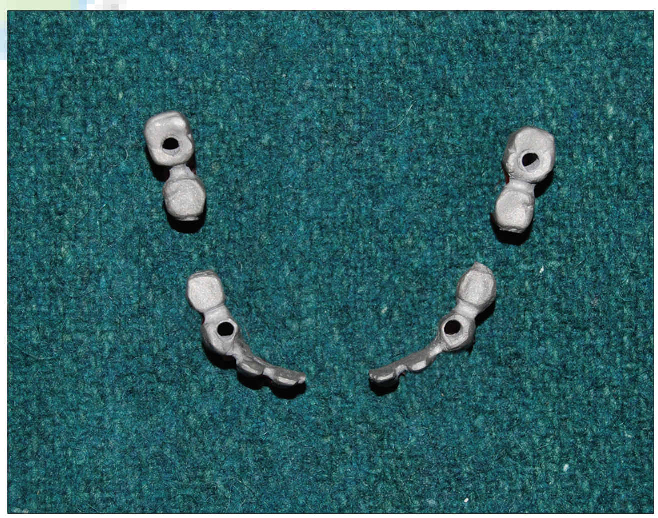

Figure 6: Sectioned implant-supported prosthesis

The results of the statistical analysis are tabulated from Table 11.

Test of normality (Shapiro–Wilk) showed a normal distribution ($P > 0.05$). Hence, parametric test, one-way ANOVA, and Scheffe's *post hoc* were performed.

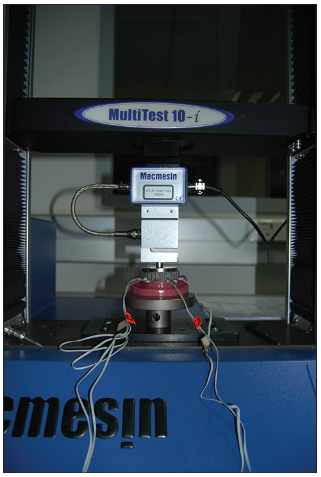

Figure 7: Load application on the model using universal testing machine

The mean difference was significant at the 0.05 level which means that $P \leq 0.05$ (significant) is considered as statistically significant.

DISCUSSION

Precise fit between the abutments and superstructure is an important factor in determining the long-term success of an implant-supported prosthesis. Passive fit though desirable is not clinically obtainable. Passive fit means that framework induces zero strain on the implant and the surrounding bone in the absence of an external load.[3] The clinical and laboratory procedures employed in the fabrication of framework are inadequate to provide a passive fitting superstructure. When the passivity in superstructure is not achieved, forces are generated in the bone around the implant which may result in loosening of the prosthesis or abutment screws and fracture of the framework or implant body.[5] Watanabe *et al.* stated that such a situation may even lead to loss of osseointegration.[2] According to Vasconcellos *et al.*, when an occlusal load is applied on an implant-supported prostheses, the load is partially transferred to bone, with the highest stress occurring in the peri-implant area.[6] Therefore, the cervical region of implant is the site where the greatest microdeformation occurs independent of the type of bone, the design of implant, the configuration of prosthesis, and the type of load applied. Himmlová *et al.* stated that bone strain above 3000 microstrains may be unfavorable for the bone leading to a hypertrophic response and bone strain above 4000 microstrains may cause overloading followed by bone loss.[7] Complete passivity in one-piece casting is hard to achieve, but improvement in the fit of implant-supported framework can be achieved by sectioning the framework and then reuniting the sectioned framework.[8] The need for this study was to develop a clinical approach to reduce the stresses induced on the bone surrounding the implant since these stresses on exceeding the physiological limit of the bone can cause crestal bone loss and loss of osseointegration. This study was done to evaluate the strain developed in simulated mandibular model before and after the joining of an implant-supported screw-retained prosthesis by different techniques.

Table 1: Peri-implant strain generated in the mandibular model before sectioning of the prostheses (microstrain)

Serial number	SG							
	1	2	3	4	5	6	7	8
1	525	440	881	445	660	886	700	515
2	501	426	991	405	730	795	727	538
3	498	414	861	478	734	801	720	501
4	468	326	927	492	665	826	704	527
5	525	501	905	468	714	847	711	525
6	520	478	919	445	615	798	736	515
7	555	435	712	405	727	720	729	497
8	472	376	915	415	719	776	721	525
9	446	492	842	445	620	805	717	476
10	452	485	946	470	646	805	712	470
Mean	496.2	437.3	889.9	446.8	683.0	805.9	717.7	508.9

SG: Strain gauges

Table 2: Peri-implant strain generated in the mandibular model after sectioning of the prostheses (microstrain)

Serial number	SG							
	1	2	3	4	5	6	7	8
1	174	163	109	225	207	192	243	198
2	168	140	117	205	210	113	222	121
3	172	153	111	182	191	142	217	172
4	134	175	123	112	207	225	240	154
5	143	170	177	223	225	170	245	171
6	172	178	108	212	187	161	221	145
7	211	161	131	172	175	152	273	123
8	173	141	133	195	212	215	206	130
9	201	163	127	201	212	212	231	185
10	223	175	115	210	227	207	220	147
Mean	177.1	161.9	125.1	225.0	215.7	178.9	231.8	154.6

SG: Strain gauges

Table 3: Peri-implant strain generated in the mandibular model after joining the sectioned prostheses by arc welding (microstrain)

Serial number	SG							
	1	2	3	4	5	6	7	8
1	223	271	362	292	333	452	291	261
2	220	260	295	278	275	373	293	263
3	242	253	313	317	302	405	305	242
4	273	258	373	212	315	298	351	306
5	208	227	418	315	342	414	332	318
6	251	271	321	317	298	402	272	273
7	303	241	371	276	300	405	313	221
8	217	293	416	278	320	398	343	220
9	343	207	402	217	322	301	351	241
10	273	212	444	243	315	389	320	265
Mean	255.3	249.3	371.5	274.5	312.2	383.7	317.1	261.0

SG: Strain gauges

Table 4: Peri-implant strain generated in the mandibular model after joining the sectioned prostheses by soldering (microstrain)

Serial number	SG							
	1	2	3	4	5	6	7	8
1	212	251	242	272	253	375	215	252
2	209	232	292	218	220	315	228	217
3	221	215	285	296	248	372	225	225
4	242	248	305	201	298	282	221	278
5	192	210	372	281	273	398	252	302
6	215	252	205	263	292	393	233	248
7	275	243	301	272	252	291	272	202
8	202	225	351	243	223	323	298	212
9	256	210	375	201	212	221	292	238
10	248	208	258	213	293	357	253	248
Mean	227.2	229.4	298.6	246.0	256.4	332.7	248.9	251.5

SG: Strain gauges

Table 5: Peri-implant strain generated in the mandibular model after joining the sectioned prostheses by laser welding (microstrain)

Serial number	SG							
	1	2	3	4	5	6	7	8
1	192	195	152	232	225	239	272	217
2	186	173	194	220	231	178	258	173
3	201	192	172	221	208	195	233	215
4	178	171	175	178	229	248	272	192
5	172	206	218	203	198	201	268	212
6	152	195	145	231	205	188	251	165
7	202	210	165	185	232	179	292	171
8	193	187	155	215	251	245	246	150
9	222	208	165	235	242	227	242	191
10	250	178	158	189	238	233	252	239
Mean	194.8	191.5	173.1	210.0	225.1	213.3	258.6	192.5

SG: Strain gauges

Table 6: Mean and standard deviation before sectioning the prostheses

	SG							
	1	2	3	4	5	6	7	8
Mean	496.20	437.30	889.90	446.80	683.00	805.90	717.70	508.90
SD	35.845	55.588	75.503	30.767	46.925	43.447	11.275	22.526

SD: Standard deviation, SG: Strain gauges

Table 7: Mean and standard deviation after sectioning the prostheses

	SG							
	1	2	3	4	5	6	7	8
Mean	177.10	161.90	125.10	193.70	205.30	178.90	231.80	154.60
SD	27.906	13.609	20.322	33.173	46.925	36.988	19.153	26.039

SD: Standard deviation, SG: Strain gauges

Table 8: Mean and standard deviation after arc welding the prostheses

	SG							
	1	2	3	4	5	6	7	8
Mean	255.30	249.30	371.50	274.50	312.20	383.70	317.10	261.00
SD	43.182	27.492	49.718	39.144	19.240	48.712	27.201	32.455

SD: Standard deviation, SG: Strain gauges

Specimens simulating mandibular edentulous ridge were fabricated in heat-cured acrylic resin. Heat-cured resin was used for fabricating the models as its modulus of elasticity is closer to natural cancellous bone.[9-11] The models were designed with a slit in the center of the base to simulate the L-shape and the flexion of the mandible. Implant analogs of dimension 3.75 mm × 11.5 mm were placed in the following tooth positions; 36, 33, 43, 46. UCLA abutments were fixed to the implants. Implant-supported screw-retained fixed prostheses were fabricated in cobalt-chromium alloy and were fixed to the implants with a torque of 35 Ncm using torque wrench. Strain gauges were bonded to the acrylic models mesial and distal to each implant to record peri-implant strain on application of load. Six similar models were fabricated. 400 N of load was applied over the prostheses for a duration of 10 s using universal testing machine, and strain was measured, as in a previous study done by Vasconcellos *et al*.[6] All the prosthesis were sectioned at the area between 36 and 33, 33 and 43, and 43 and 46 using 35 μm thin carborundum disc, and strain were measured after application of load on the sectioned prosthesis.[12] Specimens were reunited under three groups, namely, arc welding, soldering, and laser welding after which they were subjected to load and strain were measured. The results were subjected to one-way ANOVA to detect statistically significant difference. When sectioning and reuniting of the superstructure was done, a significant difference was observed in the magnitude of strain between the one-piece cast method and various uniting methods. In the present study, lowest mean strain values were observed in models with sectioned prostheses (125–230 microstrains) in all the strain gauges. Whereas, models before sectioning of the prostheses showed the highest mean strain values (435–890 microstrains). Among the three joining techniques, lowest mean strain values were observed when the sectioned prostheses was reunited using laser welding technique (173–260 microstrains) whereas the prostheses reunited by arc welding showed the highest mean strain values (250–385 microstrains). Mean strain values for prostheses reunited by soldering were found to be 227-335 microstrains. Similar results were obtained in a study done by Watanabe *et al*. in which they compared the peri-implant strain generated by frameworks fabricated by one-piece casting and soldering.[2] Higher mean strain values were obtained in frameworks fabricated by one-piece casting method when compared to frameworks which were sectioned and then reunited using soldering technique. Mendes *et al*. also observed higher strain in one-piece casting (−355 microstrains) when compared to soldering technique (−0.698 microstrains).[13]

Costa *et al*. conducted a study to compare the misfit of framework fabricated by one-piece casting and cast in sections followed by laser welding and brazing.[14] Based on the results of the study, they concluded that less distortion in framework was observed when they were cast in sections and reunited by laser welding. They stated that the probable reason for the least strain generated by employing laser welding technique to reunite the sectioned prosthesis could be a small heat affected zone in the metal and the lesser amount of material added to the welded region which reduces the volume of metal that is going to contract on cooling, thus leading to less distortion of welded framework. Whereas in soldering and arc welding technique, greater heat affected zone is formed in metal causing more distortion when compared to laser welding technique. Barbi *et al.* also conducted a study to compare three different joining techniques, namely, laser welding, brazing, and tungsten inert gas welding by measuring the resulting marginal misfit in a simulated prosthetic assembly.[15] He concluded that the method used for joining Co-Cr prosthetic structures had an influence on the resulting passive fit. Frameworks joined by the tungsten inert gas method produced better mean results than did the brazing or laser welding method. The fit of a framework is determined by the impression method and the material, the dimensional stability of master cast and the fabrication process of the prostheses.[16-18] The latter is especially important when fabricating a framework by means of lost-wax method. Wax has the highest coefficient of thermal expansion of all dental materials and its dimensional stability is subject to any temperature changes.[19] During investing and casting, distortion occurs which are difficult to eliminate. If an appropriate protocol is followed, the distortion caused by the aforementioned factors is probably small and clinically insignificant.[20,21] However, a combination of distortion in different dimensions can result in significant misfit at the abutment-implant interface which can generate strain in the bone around the implants.[22,23] Barbosa *et al.* stated that any misfit of the prosthesis in relation to the implant will generate external stresses in the prosthesis, implant, and bone, and a rigid and accurate connection between prosthesis and implant is needed for the success of implant-supported prosthesis.[24] The results of the present study are consistent with the concept that it is unlikely that a perfect passive prosthesis might exist because the act of torque application transfers some strain to the abutment and/or bone.

According to the methodology used and based on the results obtained, it was concluded that highest strain value was observed in all strain gauges when single-unit prosthesis was subjected to load whereas least strain was observed when the prosthesis was sectioned and then subjected to load. Increase in strain value was observed in the strain gauges when the sectioned prosthesis was

Table 9: Mean and standard deviation after soldering the prostheses

	SG							
	1	2	3	4	5	6	7	8
Mean	227.20	229.40	298.60	246.00	256.40	332.70	248.90	242.20
SD	26.645	18.112	55.636	35.431	31.844	56.782	29.846	30.727

SD: Standard deviation, SG: Strain gauges

Table 10: Mean and standard deviation after laser welding the prostheses

	SG							
	1	2	3	4	5	6	7	8
Mean	194.80	191.50	169.90	210.90	225.90	213.30	258.60	192.50
SD	27.079	14.199	21.799	20.888	17.143	27.877	17.494	28.001

SD: Standard deviation, SG: Strain gauges

Table 11: Multiple comparisons (Scheffe's *post hoc* test)

Group (I)	Group (J)	Mean difference (I−J)	SE	Significance	95% CI	
					Lower bound	Upper bound
Before sectioning	After sectioning	319.10*	14.658	0.000	272.02	366.18
	Arc welding	240.90*	14.658	0.000	193.82	287.98
	Soldering	269.00*	14.658	0.000	221.92	316.08
	Laser welding	301.40*	14.658	0.000	254.32	348.48
After sectioning	Before sectioning	−319.10*	14.658	0.000	−366.18	−272.02
	Arc welding	−78.20*	14.658	0.000	−125.28	−31.12
	Soldering	−50.10*	14.658	0.031	−97.18	−3.02
	Laser welding	−17.70	14.658	0.833	−64.78	29.38
Arc welding	Before sectioning	−240.90*	14.658	0.000	−287.98	−193.82
	After sectioning	78.20*	14.658	0.000	31.12	125.28
	Soldering	28.10	14.658	0.461	−18.98	75.18
	Laser welding	60.50*	14.658	0.005	13.42	107.58
Soldering	Before sectioning	−269.00*	14.658	0.000	−316.08	−221.92
	After sectioning	50.10*	14.658	0.031	3.02	97.18
	Arc welding	−28.10	14.658	0.461	−75.18	18.98
	Laser welding	32.40	14.658	0.315	−14.68	79.48
Laser welding	Before sectioning	−301.40*	14.658	0.000	−348.48	−254.32
	After sectioning	17.70	14.658	0.833	−29.38	64.78
	Arc welding	−60.50*	14.658	0.005	−107.58	−13.42
	Soldering	−32.40	14.658	0.315	−79.48	14.68

CI: Confidence interval, SE: Standard error, Significant $p\leq.05$

joined by any of the methods and subjected to load, but the values were below those obtained with single-unit prosthesis. Based on the results of this study, the hypothesis of the study was rejected and it was recommended that any long-span implant prosthesis should be sectioned and then reunited preferably by laser welding technique to control the peri-implant strain generated in the surrounding bone.

CONCLUSIONS

The following conclusions were drawn from the present study:

1. Highest strain value was observed in all the strain gauges when single-unit prostheses were subjected to load whereas least strain was observed when the prostheses were sectioned and then subjected to load
2. Increase in strain value was observed in the strain gauges when the sectioned prostheses were joined and subjected to load, irrespective of the technique used (arc welding, soldering, and laser welding), but the values were below those obtained with single-unit prostheses
3. Among the three techniques used for the joining of sectioned prostheses, least strain was observed in all the strain gauges when laser welding was used whereas highest strain was observed when arc welding technique was used
4. Long-span implant prosthesis has to be sectioned and united to control the strain generated in bone around the implants.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Tashkandi EA, Lang BR, Edge MJ. Analysis of strain at selected bone sites of a cantilevered implant-supported prosthesis. J Prosthet Dent 1996;76:158-64.
2. Watanabe F, Uno I, Hata Y, Neuendorff G, Kirsch A. Analysis of stress distribution in a screw-retained implant prosthesis. Int J Oral Maxillofac Implants 2000;15:209-18.
3. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: Current status. Implant Dent 2001;10:85-92.
4. Kunavisarut C, Lang LA, Stoner BR, Felton DA. Finite element analysis on dental implant-supported prostheses without passive fit. J Prosthodont 2002;11:30-40.
5. Luk HW, Pow EH, McMillan AS, Hui CF. A double casting technique to minimize distortion when constructing fixed partial dentures on implants. J Prosthet Dent 2004;91:93-6.
6. Vasconcellos LG, Nishioka RS, Vasconcellos LM, Nishioka LN. Effects of axial loads on implant supported partial fixed prosthesis by strain gauge analysis. J Appl Oral Sci 2011;19:610-5.
7. Himmlová L, Dostálová T, Kácovský A, Konvicková S. Influence of implant length and diameter on stress distribution: A finite element analysis. J Prosthet Dent 2004;91:20-5.
8. Eskitascioglu G, Usumez A, Sevimay M, Soykan E, Unsal E. The influence of occlusal loading location on stresses transferred to implant-supported prostheses and supporting bone: A three-dimensional finite element study. J Prosthet Dent 2004;91:144-50.
9. Natali AN, Pavan PG, Ruggero AL. Evaluation of stress induced in peri- implant bone tissue by misfit in multi- implant prosthesis. J Dent 2006;22:388-95.
10. Rani I, Shetty J, Reddy V. A comparison of peri-implant strain generated by different types of implant supported prostheses. J Indian Prosthodont Soc 2017;17:142-8.
11. Vidya Bhat S, Premkumar P, Kamalakanth Shenoy K. Stress distribution around single short dental implants: A Finite element study. J Indian Prosthodont Soc 2014;14:161-7.
12. Tiossi R, Falcão-Filho H, Aguiar FA Jr., Rodrigues RC, Mattos Mda G, Ribeiro RF, *et al.* Modified section method for laser-welding of ill-fitting cp Ti and Ni-Cr alloy one-piece cast implant-supported frameworks. J Oral Rehabil 2010;37:359-63.
13. Mendes SD, Rezende CE, Neto RT, Souse EA, Rubo JH. Effect of framework soldering on the deformation of implant abutments after framework seating: A study with strain gauges. Implants Dent 2013;1:1-6.
14. Costa EM, Neisser MP, Bottino MA. Multiple-unit implant frames: One-piece casting vs. Laser welding and brazing. J Appl Oral Sci 2004;12:227-31.
15. Barbi FC, Camarini ET, Silva RS, Endo EH, Pereira JR. Comparative analysis of different joining techniques to improve the passive fit of cobalt-chromium superstructures. J Prosthet Dent 2012;108:377-85.
16. Yokoyama S, Wakabayashi N, Shiota M, Ohyama T. The influence of implant location and length on stress distribution for three-unit implant-supported posterior cantilever fixed partial dentures. J Prosthet Dent 2004;91:234-40.
17. Jackson BJ. The use of laser-welded titanium framework technology: A case report for the totally edentulous patient. J Oral Implantol 2005;31:294-300.
18. Savadi RC, Agarwal J, Agarwal RS, Rangarajan V. Influence surface topography and loading condition on stress distribution in bone around implant: A Finite element analysis. Indian Prosthodont Soc 2011;11:221-31.
19. Abduo J, Lyons K, Bennani V, Waddell N, Swain M. Fit of screw-retained fixed implant frameworks fabricated by different methods: A systematic review. Int J Prosthodont 2011;24:207-20.
20. Silva TB, De Arruda Nobilo MA, Pessanha Henriques GE, Mesquita MF, Guimaraes MB. Influence of laser-welding and electroerosion on passive fit of implant-supported prosthesis. Stomatologija 2008;10:96-100.
21. Hollweg H, Jacques LB, da Silva Moura M, Bianco VC, Souza EA, Rubo JH, *et al.* Deformation of implant abutments after framework connection using strain gauges. J Oral Implantol 2012;38:125-32.
22. Tiossi R, Falcão-Filho HB, de Aguiar FA Jr., Rodrigues RC, de Mattos Mda G, Ribeiro RF, *et al.* Prosthetic misfit of implant-supported prosthesis obtained by an alternative section method. J Adv Prosthodont 2012;4:89-92.
23. Yannikakis S, Prombonas A. Improving the fit of implant prosthetics: An *in vitro* study. Int J Oral Maxillofac Implants 2013;28:126-34.
24. Barbosa GA, das Neves FD, de Mattos Mda G, Rodrigues RC, Ribeiro RF. Implant/abutment vertical misfit of one-piece cast frameworks made with different materials. Braz Dent J 2010;21:515-9.