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

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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

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
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.

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 prostheses 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.

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.
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. 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. Watanabe et al. stated that such a situation may even lead to loss of osseointegration. 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. 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. 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. 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 | SG 2 | SG 3 | SG 4 | SG 5 | SG 6 | SG 7 | SG 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|

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

| Serial number | SG 1 | SG 2 | SG 3 | SG 4 | SG 5 | SG 6 | SG 7 | SG 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          | 171.1| 161.9| 125.1| 225.0| 215.7| 178.9| 231.8| 154.6|

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

| Serial number | SG 1 | SG 2 | SG 3 | SG 4 | SG 5 | SG 6 | SG 7 | SG 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| 371.7| 261.0|

SG: Strain gauges
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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             | 192 | 195 | 152 | 232 | 222 | 225 | 253 | 379 | 215 |
| 2             | 201 | 191 | 172 | 221 | 218 | 219 | 233 | 218 | 217 |
| 3             | 178 | 171 | 175 | 178 | 219 | 248 | 272 | 192 | |
| 4             | 172 | 206 | 218 | 203 | 198 | 201 | 268 | 212 | |
| 5             | 152 | 195 | 145 | 231 | 205 | 188 | 251 | 165 | |
| 6             | 202 | 210 | 165 | 185 | 232 | 179 | 292 | 171 | |
| 8             | 193 | 217 | 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 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             | 212 | 251 | 242 | 272 | 253 | 253 | 375 | 215 | 252 |
| 2             | 209 | 232 | 292 | 218 | 220 | 315 | 228 | 217 | |
| 3             | 231 | 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 | 293 | 233 | 248 | |
| 7             | 275 | 243 | 301 | 272 | 252 | 291 | 272 | 202 | |
| 8             | 202 | 225 | 351 | 243 | 232 | 298 | 212 | 192 | |
| 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 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 |

SG: 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 | 36.998 | 19.153 | 26.039 |

SG: 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 |

SG: 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.\[11\] 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.\[8\] All the prostheses 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.\[1\] 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.\[13\] 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.\[15,22,23\] 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

|     | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    |
|-----|------|------|------|------|------|------|------|------|
| Mean| 227.20| 229.40| 298.60| 246.00| 256.40| 332.70| 210.90| 225.90|
| 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

|     | 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          |
|-----------|-----------|-----------------------|------|--------------|-----------------|
|           | Before 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 | 315.08          |
|           | 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           |
|           | Soldering       | 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 ≤ .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 (are 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.

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