ACP
AMERICAN COLLEGE OF PROSTHODONTISTS®

Influence of Different Tightening Forces Before Laser Welding to the Implant/Framework Fit

Clebio Domingues da Silveira-Júnior, DDS, MS, Flávio Domingues Neves, DDS, MS, PhD, Alfredo Júlio Fernandes-Neto, DDS, MS, PhD, Célio Jesus Prado, DDS, MS, PhD, & Paulo César Simamoto-Júnior, DDS, MS, PhD

Department of Fixed Prosthodontics, Occlusion and Dental Materials, Dental School of Federal University of Uberlandia, Minas Gerais, Brazil

Keywords
Laser welding; dental implants; dental soldering; marginal fit; torque; titanium.

Correspondence
Clebio Domingues da Silveira-Júnior, Dental School of Federal University of Uberlandia-Fixed Prosthodontics, Occlusion and Dental Materials, Av. Pará, 1720-Bl 2B, Sl 2B01, Uberlândia Minas Gerais 38400-902, Brazil.
E-mail: clebiodomingues@yahoo.com.br

Accepted February 29, 2008

doi: 10.1111/j.1532-849X.2008.00418.x

Abstract

Purpose: The aim of the present study was to evaluate the influence of abutment screw tightening force before laser welding procedures on the vertical fit of metal frameworks over four implants.
Materials and Methods: To construct the frameworks, prefabricated titanium abutments and cylindrical titanium bars were joined by laser welding to compose three groups: group of manual torque (GMT), GT10 and GT20. Before welding, manual torque simulating routine laboratory procedure was applied to GTM. In GT10 and GT20, the abutment screws received 10 and 20 Ncm torque, respectively. After welding, the implant/framework interfaces were assessed by optical comparator microscope using two methods. First, the single screw test (SST) was used, in which the interfaces of the screwed and non-screwed abutments were assessed, considering only the abutments at the framework extremities. Second, the interfaces of all the abutments were evaluated when they were screwed.
Results: In the SST, intergroup analysis (Kruskal Wallis) showed no significant difference among the three conditions of tightening force; that is, the different tightening force before welding did not guarantee smaller distortions. Intragroup analysis (Wilcoxon) showed that for all groups, the interfaces of the non-screwed abutments were statistically greater than the interfaces of the screwed abutments, evidencing distortions in all the frameworks. ANOVA was applied for the comparison of interfaces when all the abutments were screwed and showed no significant difference among the groups.
Conclusions: Under the conditions of this study, pre-welding tightness on abutment screws did not influence the vertical fit of implant-supported metal frameworks.

Dental treatments using osseointegrated titanium implants have been recognized and established by research that began over 40 years ago.[1] Since then, new techniques and technologies have been added to the initial protocol to optimize known procedures. One of the main objectives of current research is to develop means of fabricating implanted dental prostheses with increasingly better fits among the components, as this is one of the main determinants of treatment longevity.[2-5]

The load falling on the non-passive dental prosthetic system could result in mechanical complications, such as loosening or fracture of screws, fractures of components and of the implant itself,[6,7] and biological complications, such as mucositis, peri-implantitis, and loss of osseointegration.[8,9]

Different clinical and laboratory methods have been suggested for optimizing the fit of implant-supported prosthetic frameworks, among them laser welding of cast parts,[10] electrical discharge machining,[11-13] and splinted transfers impression.[14]

In dentistry, the use of laser welding has expanded with the advent of implant-supported prostheses, due to the concern about the need for passive fit inherent to these treatments. Moreover, the speed of the procedures favors their use in immediate loading techniques. The advantages of using laser welding have been demonstrated in various studies,[15] although there are still difficulties and limitations. There is no clear information in the literature regarding the parameters for optimizing joints between titanium parts.[16-18] One perceives that the techniques for dental prostheses have no reference protocol to be followed, and the results of one's work depend on one's technical skill and experience obtained through trial and error.

The tightness applied to abutments or prosthesis fixation screws alters the level of fit among the components;[19,20] however, it is not a routine procedure for laboratories to control the screw tightening force on metal frameworks by a torque controller device before performing welds. Generally, screws receive manual tightness before welding.

In this context, there is a hypothesis that the framework of implanted prostheses would present better fit after laser welding if the tightening force applied to the screws was controlled before the welding procedure. This being so, the aim of this study was to assess the influence of the tightening force applied to abutment screws before laser welding, and if possible, identify the tightness that would provide the best metal framework fit.

Materials and methods

A master cast was made of aluminum, in which four implants, 3.75 mm in diameter and 10 mm in height (Master Screw, Conexão Sistemas de Próteses, São Paulo, Brazil) were placed parallel to each other but at variable distances, as occurs in the majority of clinical situations (Fig 1).

Five working casts with implant analogs (013020, Conexão Sistemas de Próteses) were fabricated from five separated impressions of the master cast with the splinted impression technique and open custom tray.[21] The transfers were positioned over the implants and joined using metallic pins and acrylic resin (Duralay, Reliance Dental Co., Worth, IL) (Fig 2). This technique ensures the maintenance of the transfers' positions and prevents their rotation within the impression. Regular viscosity polyether (Impregum-F®, 3M ESPE, Seefeld, Germany) was used as the impression material.

As a control, all abutment screws were manually tightened to the implants and assessed by scanning electronic microscopy (LEO-435 VP, Carl Zeiss, Oberkochen, Germany) at 500 × magnification to ensure that all abutments presented the same standard fit to the implants.

Twenty abutments and cylindrical titanium bars (055024/Laser Abutment, 400204/Laser Bars; Conexão Sistemas de Próteses) were used to construct five metal frameworks for each group (Fig 3).

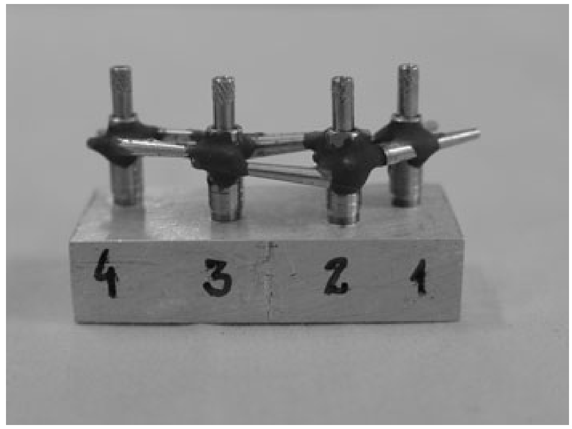

Figure 2 Splinted impression technique.

Before laser welding, the abutment screws received the following tightening forces: Group GTM—manual torque, Group GT10—10 Ncm torque, Group GT20—20 Ncm torque. The screws were tightened in GT10 and GT20 with a torque controller device (Conexão Sistemas de Próteses).

To study the passivity of the frameworks, the Sheffield test or single screw test (SST) was used[11,12] on the master cast, in which only one screw was tightened; first the one on the left extremity (#1) and then on the right extremity (#4). The vertical fit interfaces between implants/framework were measured on both sides and were termed screwed and non-screwed side. The readings were done in the proximal surfaces, mesial and distal, on the screwed and non-screwed abutments (Fig 4). The interfaces were also evaluated when all the abutments were screwed with a tightening force of 20 Ncm over the implants of the master cast. The readings were performed with an optical comparator microscope at 40 × magnification (Mitutoyo TM-500, Tokyo, Japan). All readings, including that done in the SST, were repeated three times by the same operator to obtain the mean value.

The interface values were statistically analyzed and discussed considering three tightening conditions: interface values of screwed abutments, interface values of non-screwed abutments (both were obtained by SST), and interface values when

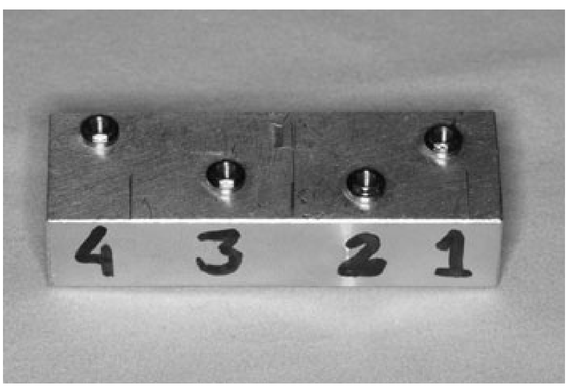

Figure 1 Master cast in aluminum.

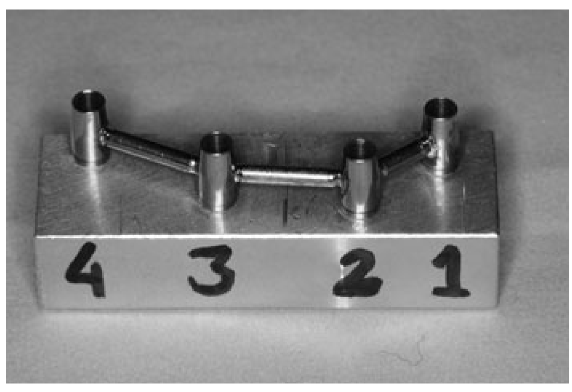

Figure 3 Metal framework after welding the bars.

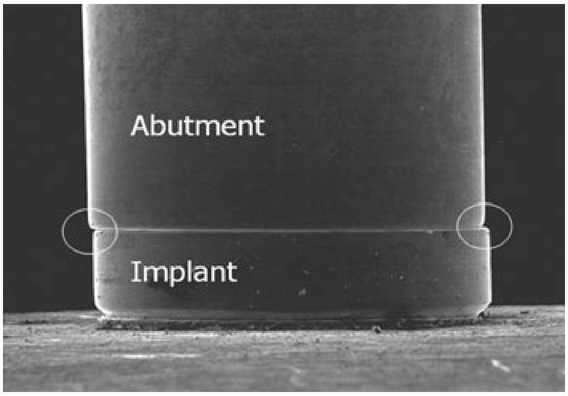

Figure 4 SEM photo at 50 × magnification, illustrating the mesial and distal interface regions assessed.

all abutment screws were tightened. The statistical tests used were the Kruskal Wallis and Wilcoxon tests for comparisons among the interface values found in the SST and ANOVA for the comparisons among the interface values found when all the abutment screws were tightened ($p < 0.05$). SPSS 12.0 for Windows software (SPSS, Inc., Chicago, IL) was used.

Results

The mean interface values observed by SST are presented in Table 1. For intragroup comparisons, screwed side versus non-screwed side, the non-parametric Wilcoxon test was used. In the three groups, the values showed the same behavior: there were significant differences ($p \leq 0.05$) with the interface values of the screwed abutments lower than the interface values of the non-screwed abutments.

The Kruskal Wallis Test was used for intergroup comparisons. First, the interface values of the screwed abutments in the three groups were compared, and then the interface values of the non-screwed abutments were compared. For both comparisons, no significant differences were found ($p > 0.05$).

The mean interface values when all the abutment screws were tightened with 20 Ncm are shown in Table 2. ANOVA was used. No significant difference was found among the three groups (μm) (GTM $= 9.13 \pm 7.35$; GT10 $= 7.54 \pm 6.16$; GT20 $= 7.47 \pm 6.69$; $p > 0.05$).

Furthermore, with all abutment screws tightened, the interface values before and after welding were also compared, using the Wilcoxon test. No significant differences were found for any of the groups (Fig 5; $p > 0.05$).

Discussion

The tested hypothesis was not confirmed. The fit interface between implants/frameworks was not influenced by the tightening force applied to the abutment screws before welding. Some important points regarding the methodology used and the results obtained should be discussed.

Inherent to laser welding procedures, there are some variables capable of influencing the final results of the joints. The present study focused the tightening force on the abutment screw to the analogs in the working cast before laser welding was performed.

SST was used to assess the passive fit of dental prosthetic frameworks after welding.[11,12] The distortions caused by welding were characterized by the creation of a gap (interface) between the abutment and implant on the vertical axis when a single abutment was screwed. Therefore, the larger the vertical interfaces created by tightening a single screw, the larger the distortions were considered to be.

There are other methods for assessing the fit of implant-supported dental prosthetic frameworks,[10,22–25] but the SST is a simple, economic, and feasible method to use clinically and in dental laboratories. This justifies its use in this study.

By the intragroup statistical analyses, the interface values of the SST were compared between the screwed and non-screwed abutments for the three groups separately. In all analyses, the results were statistically different, and the interface value means for the non-screwed abutments were significantly higher. This result indicates that no specimen obtained passive fit, and this is in agreement with the affirmations of Wee et al[13] in a literature review.

The intergroup analyses showed no significant difference among the three groups for two tightening conditions in the SST. The pre-welding torque of 10 Ncm in group GT10 and 20 Ncm in group GT20 did not guarantee parts with smaller

Table 1 Mean (mesial and distal) interface values (in μm) in accordance with the different tightening conditions in the single screw test

		GTM		GT10		GT20	
Framework		Screwed abutments	Non-screwed abutments	Screwed abutments	Non-screwed abutments	Screwed abutments	Non-screwed abutments
A	Implant 1	14.5	23	6.5	106.83	8.66	211.66
	Implant 4	9.5	29.5	24.16	38.16	7.66	215.33
B	Implant 1	29	128.8	17.16	136.33	17.17	242.66
	Implant 4	11.65	42.15	11.33	19.74	6.83	37.83
C	Implant 1	11	33	13.17	269.33	15.5	199.33
	Implant 4	14.65	49.8	9.66	142.16	8.16	98
D	Implant 1	0	100	0	135.33	2.83	71.67
	Implant 4	9	33.6	10.16	47.16	5.83	22.83
E	Implant 1	5.15	23.8	7.16	22.5	7.83	88.66
	Implant 4	10.15	23.3	0	8.33	6	29.83

Table 2 Mean interface values (in μm) when all abutment screws were tightened

		GTM	GT10	GT20
Framework A	Implant 1	0.00	3.16	4.33
	Implant 2	16.50	0.00	0.00
	Implant 3	4.00	11.83	12.50
	Implant 4	3.50	10.66	0.00
Framework B	Implant 1	26.10	11.83	19.16
	Implant 2	10.00	10.83	4.33
	Implant 3	14.50	11.33	12.00
	Implant 4	6.30	0.00	0.00
Framework C	Implant 1	9.00	5.16	13.50
	Implant 2	13.65	9.83	14.50
	Implant 3	8.45	13.50	17.50
	Implant 4	0.00	7.00	0.00
Framework D	Implant 1	4.15	0.00	0.00
	Implant 2	11.45	15.70	9.66
	Implant 3	10.60	0.00	5.00
	Implant 4	2.15	0.00	0.00
Framework E	Implant 1	4.30	6.33	6.16
	Implant 2	22.00	17.33	13.83
	Implant 3	16.00	16.33	16.83
	Implant 4	0.00	0.00	0.00

distortions. The interface values for the non-screwed abutments were statistically similar. Linear distortions occurred, characterized by interface measurements (gaps) on the vertical axis for all the groups, irrespective of the amount of pre-welding screw tightening force. Probably, the shrinkage force generated by weld cooling was higher than the abutment screw capacity to prevent displacements.

In addition to the SST, the welded frameworks were analyzed after the application of 20 Ncm torque on all the screws. There was also no significant difference for the three groups. Group GTM had the highest mean interface value when all the abutment screws were tightened (9.13 ± 7.34 μm), nevertheless, it is in agreement with values found in the literature.[26] The 20-Ncm torque on all abutment screws over the implants in the master cast made the implant/framework interface values acceptable. In spite of distortions having occurred after welding, as was shown by the SST, the force generated by the torque significantly improved the implant/framework fit. These results showed that clinically, the fit of implant-supported frameworks should be assessed without tightening all the screws, and that

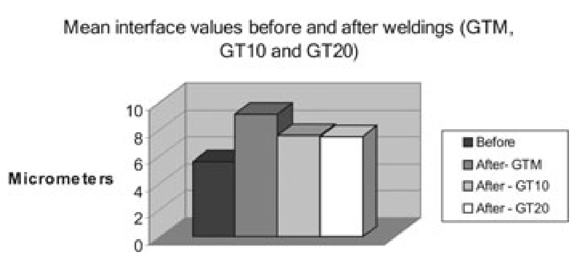

Figure 5 Mean interface values before and after laser welding.

radiographs taken of completely screwed frameworks do not evidence non-passive frameworks.

It is important to consider that manual tightening for group GTM was performed by a technician experienced in laser-welding procedures. Although the results have not demonstrated differences in the vertical adjustments of frameworks for the three groups (GTM, GT10, GT20), it is not known whether this experience could influence the results. Therefore, the use of a torque controller device is recommended to guarantee standardized framework tightening before welding, particularly by inexperienced technicians.

The torque applied to abutment screws was only one among various technical procedures that could influence the final result of laser-welded prosthetic work. There are other variables that must still be studied until optimization of these procedures is achieved. It is also suggested that in future studies, horizontal fit among components be analyzed.

Conclusions

Considering the results obtained with the methodology used in this study, it was concluded that there was no significant difference in the vertical fit of metal frameworks when the screws received different tightening forces (manual, 10, or 20 Ncm) before laser welding.

Acknowledgments

The components used in this study were provided by Conexão Sistema de Prótese Ltda, São Paulo, Brazil. The laser weldings were provided by the technician Marco Aurélio Dias Galbiati.

References

1. Albrektsson T, Zarb G, Worthington P, et al: The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11-25
2. Hecker DM, Eckert SE: Cyclic loading of implant-supported prostheses: changes in component fit over time. J Prosthet Dent 2003;89:346-351
3. Skalak R: Biomechanical considerations in osseointegrated prostheses. J Prosthet Dent 1983;49:843-848
4. Jemt T: Failures and complications in 391 consecutively inserted fixed prostheses supported by Branemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants 1991;6:270-276
5. Sahin S, Cehreli MC: The significance of passive framework fit in implant prosthodontics: current status. Implant Dent 2001;10:85-92
6. Kallus T, Bessing C: Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5 years. Int J Oral Maxillofac Implants 1994;9:169-178
7. Neves FD, Fernandes Neto AJ, Mendonça G, et al: Fratura de implantes—Relato de Casos Clínicos. RBP—Revista Brasileira de Implantodontia e Prótese sobre Implante 2005;12:21-26
8. Jemt T, Book K: Prosthesis misfit and marginal bone loss in edentulous implant patients. Int J Oral Maxillofac Implants 1996;11:620-625

9. Lang NP, Wilson TG, Corbet EF: Biological complications with dental implants: their prevention, diagnosis and treatment. Clin Oral Implants Res 2000;11(Suppl. 1):146-155
10. Riedy SJ, Lang BR, Lang BE: Fit of implant frameworks fabricated by different techniques. J Prosthet Dent 1997;78:596-604
11. Eisenmann E, Mokabberi A, Walter MH, et al: Improving the fit of implant-supported superstructures using the spark erosion technique. Int J Oral Maxillofac Implants 2004;19:810-818
12. Sartori IA, Ribeiro RF, Francischone CE, et al: In vitro comparative analysis of the fit of gold alloy or commercially pure titanium implant-supported prostheses before and after electroerosion. J Prosthet Dent 2004;92:132-138
13. Wee AG, Aquilino SA, Schneider RL: Strategies to achieve fit in implant prosthodontics: a review of the literature. Int J Prosthodont 1999;12:167-178
14. Nissan J, Gross M, Shifman A, et al: Stress levels for well-fitting implant superstructures as a function of tightening force levels, tightening sequence, and different operators. J Prosthet Dent 2001;86:20-23
15. Souza PCRD, Dinato JC, Beatrice CRS, et al: Soldagem na odontologia : Estudo de uniões soldadas empregando laser e brasagem. Rev APCD 2000;54:470-475
16. Chai T, Chou CK: Mechanical properties of laser-welded cast titanium joints under different conditions. J Prosthet Dent 1998;79:477-483
17. Wang RR, Welsch GE: Joining titanium materials with tungsten inert gas welding, laser welding, and infrared brazing. J Prosthet Dent 1995;74:521-530
18. Yamagishi T, Ito M, Fujimura Y: Mechanical properties of laser welds of titanium in dentistry by pulsed Nd:YAG laser apparatus. J Prosthet Dent 1993;70:264-273
19. Barbosa GAS, Simamoto Júnior PC, Fernandes Neto AJ, et al: Effect of different torque levels on the implant/abutment interface using castable "UCLA" abutments. Braz J Oral Sci 2005;14:912-922
20. Gross M, Abramovich I, Weiss EI: Microleakage at the abutment-implant interface of osseointegrated implants: a comparative study. Int J Oral Maxillofac Implants 1999;14:94-100
21. Assif D, Marshak B, Schmidt A: Accuracy of implant impression techniques. Int J Oral Maxillofac Implants 1996;11:216–222
22. Jemt T, Rubenstein JE, Carlsson L, et al: Measuring fit at the implant prosthodontic interface. J Prosthet Dent 1996;75:314-325
23. Kan JY, Rungcharassaeng K, Bohsali K, et al: Clinical methods for evaluating implant framework fit. J Prosthet Dent 1999;81:7–13
24. Jemt T, Lie A: Accuracy of implant-supported prostheses in the edentulous jaw: analysis of precision of fit between cast gold-alloy frameworks and master casts by means of a three-dimensional photogrammetric technique. Clin Oral Implants Res 1995;6:172-180
25. May KB, Edge MJ, Russell MM, et al: The precision of fit at the implant prosthodontic interface. J Prosthet Dent 1997;77:497-502
26. Koke U, Wolf A, Lenz P, et al: In vitro investigation of marginal accuracy of implant-supported screw-retained partial dentures. J Oral Rehabil 2004;31:477-482