ARE SECTIONING AND SOLDERING OF SHORT-SPAN IMPLANT-SUPPORTED PROSTHESES NECESSARY PROCEDURES?

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ABSTRACT

The aim of this study was to evaluate the fit between dental abutments and the metal framework of a 3-unit fixed prosthesis screwed to two implants to determine whether sectioning and soldering of the framework are in fact necessary procedures. The study was based on a model of a metal framework of a 3-unit prosthesis screwed to two implants. A total of 18 metal frameworks were constructed and divided into 3 groups: (1) NS group - each framework was cast in one piece and not sectioned; (2) CS group - the components of each sectioned framework were joined by conventional soldering; and (3) LW group - the components of each sectioned framework were joined by laser welding. The control group consisted of six silver-palladium alloy copings that were not cast together. Two analyses were mperformed: in the first analysis, the framework was screwed only to the first abutment, and in the second analysis, the framework was screwed to both abutments. The prosthetic fit was assessed at a single point using a measuring microscope (Measurescope, Nikon, Japan) and the marginal gap was measured in micrometers. Statistical analysis was performed using analysis of variance (ANOVA), Scheffe's test, Student's t-test, and Mann-Whitney U test. The NS group had larger marginal gaps than the other groups (p<0.01), while the CS and LW groups had a similar degree of misfit with no significant difference between them. The results revealed that, in the case of short-span 3-unit fixed prostheses, the framework should be sectioned and soldered or welded to prevent or reduce marginal gaps between the metal framework and dental abutments.

Key words: dental soldering; dental prosthesis; implant-supported; dental marginal adaptation.

SÃO NECESSÁRIOS OS PROCEDIMENTOS DE SECÇÃO E SOLDAGEM NAS PRÓTESES SOBRE IMPLANTES DE PEQUENA EXTENSÃO?

RESUMO

O objetivo deste estudo é avaliar o desajuste entre o intermediário protético e a infra-estrutura metálica de uma prótese fixa de três elementos aparafusada sobre dois implantes, observando se os procedimentos de seccionamento da peça e posterior soldagem são realmente necessários. O estudo foi baseado em um modelo que reproduziu a infra-estrutura metálica de uma prótese fixa de três elementos aparafusada sobre dois implantes. E de um total de dezoito infra-estruturas metálicas foram formados três grupos: no grupo NS as peças foram fundidas em monobloco e não foram seccionadas; no grupo CS as peças receberam uma soldagem convencional e no grupo LW as peças foram soldadas a laser. Seis copings de prata paládio que não receberam fundição constituíram o grupo controle. Duas análises foram realizadas: a primeira com a infra-estrutura aparafusada somente no primeiro intermediário protético e a segunda com a infra-estrutura aparafusada nos dois intermediários protéticos. As análises dos desajustes ocorreram em um único ponto e foram realizadas em um microscópio óptico de ferramentaria da marca Nikon-Japão, registrando os gaps em micrômetros. Os resultados foram submetidos à análise de variância ANOVA, teste de Scheffe, t Student e Mann Whitney. O grupo NS mostrou os maiores valores de desajuste (p<0.01). Os grupos CS e LW mostraram níveis similares de desajuste sem significância estatística. Os resultados demonstraram que mesmo para próteses pouco extensas com apenas três elementos a infra-estrutura deve ser seccionada e soldada para evitar ou reduzir os gaps entre a infra-estrutura metálica e os intermediários protéticos.

Palavras-chave: soldagem em odontologia, prótese dentária fixada por implante, adaptação marginal dentária.

INTRODUCTION

The proper fit of implant-supported prostheses has been recognized as a fundamental prerequisite for successful oral rehabilitation. Poor fit has been reported as the major cause of failure of implant-supported prostheses. Long-span frameworks are usually constructed in two or more parts to reduce marginal gaps between dental abutments and the superstructure. However, is sectioning and soldering in fact necessary in short-span fixed prosthesis? Bränemark was the first to define passive fit and to suggest a marginal gap of 10 μm to enable bone maturation and remodeling in response to occlusal loads[1]. Other authors suggested that frameworks with marginal gaps greater than 30 μm over more than 10% of the circumference of the abutment interface are considered unacceptable[2]. Another study defined passive fit as the level of fitness that does not cause any long-term clinical complications, and suggested that marginal gaps less than 150 μm were acceptable[3].

In a comparative *in vivo* study[4], it was observed that the passive fit of prostheses was not easily achieved or measured in clinical settings with current technology. It was also found that, from a clinical standpoint, none of the prostheses used in the study presented a completely passive fit to multiple implants[4]. Another study showed that marginal gaps of 30 μm, not detectable clinically, were present on 90% of the surface between the dental abutment and superstructure[5].

A protocol of tests to evaluate passive fit and a list of factors that affect this evaluation have been established elsewhere[6]. The authors observed that the capacity of the screw may mask misfits; in cases of marginal gaps up to 500 μm for 3-unit fixed prostheses supported by two implants, a misfit could not be observed after the gold screws were tightened to 10 Ncm, as they closed the gap. This suggests that the fit was achieved because of an excessive torque on the gold screws, which can result in stress fractures[6].

A study compared the vertical misfit of 3-unit implant-supported prostheses in three situations: as cast, after sectioning and laser welding, and after simulated porcelain firing heat treatment. The prostheses were constructed from either a nickel-chromium alloy or a cobalt-chromium alloy or commercially pure titanium. The authors reported that all the materials were suitable for casting implant-supported prostheses[7].

In an *in vivo* study using a polyvinyl siloxane impression material to record the gap between the superstructure and transmucosal abutments, it was found that large gaps were present in superstructures previously considered to have a clinically acceptable fit. The gaps were reduced in the vertical direction by hand-tightening the gold screws[8].

The combined use of prosthetic components constructed by different dental laboratories may lead to misfit between parts[9]. Loosening of one or more prosthesis-retaining screws may subject multiple-unit prostheses to overload[10], which is one of the most common complications in implant-supported prostheses[11].

In a review of literature on strategies to improve fit in implant prosthodontics, it was found that many authors had used welding to improve the fit of implant-supported prostheses, and that the highest accuracy was achieved by using a two-piece casting technique combined with laser welding[12]. Other authors reported that when frameworks were sectioned diagonally, there was a decrease in the levels of prosthetic misfit of implant-supported prostheses compared to one-piece casting[13,14].

Because of complications associated with misfit of screw-retained prostheses, multiple-implant supported prostheses require a more accurate technique in which several steps are necessary[15]. In such cases, a certain level of distortion is considered inevitable[16]. Some authors applied finite-element analysis to investigate the use of washers as a means of preventing screws from loosening, and concluded that the washers tested could reduce, but not eliminate screw loosening[17, 18].

In order to minimize misfit during framework construction, some procedures have been developed, such as the use of alternative impression techniques, low-fusion point metals, and framework sectioning followed by soldering or welding. The sectioning of the framework may reduce misfits, but does not lead to an absolute passive fit. Prostheses that have been soldered or welded seem to better compensate for misfits. However, passive fit depends on the expertise of the clinician and laboratory technician in the use of procedures to reduce marginal gaps and techniques that allow the correct evaluation of fit.

There is still no consensus on whether soldering or laser welding produces the best results in short-span implant-supported prostheses. Therefore, the aim of the present *in vitro* study was to examine the fit between the metal framework and dental abutments of a 3-unit prosthesis screwed to two implants to determine which joining technique, soldering or laser welding, produces the best fit of short-span implant-supported prostheses and to confirm whether sectioning is in fact necessary.

MATERIALS AND METHODS

The acrylic resin master cast

An acrylic resin master cast was constructed in an attempt to reproduce a clinical situation in which two implants (Master Screw, Conexão Sistemas de Prótese, São Paulo, Brazil) supported a 3-unit screw-retained fixed prosthesis. The center-to-center distance between the two implants was 15 mm (Fig. 1 and 2).

Construction of frameworks

Two dental abutments (Microscone, Conexão Sistemas de Prótese, São Paulo, Brazil) of 3 mm height were attached to the implants and tightened to 32 Ncm (Fig. 3). Next, transfer devices were attached to both abutments and an impression was made with vinyl polysiloxane impression material (3M Express STD putty, 3M do Brasil Ltda, São Paulo, Brazil), using the closed tray impression technique. Two replicas of the abutments were connected to the transfer devices, in order to obtain a working cast after type IV dental stone was poured into the impression.

After the working cast was obtained, the construction of the prosthesis framework began. A silver-palladium alloy (Pors-on 4, Degussa Dental, São Paulo, Brazil) was cast onto prefabricated silver-palladium caps (ConexãoSistema de Próteses, São Paulo, Brazil).

A total of 18 metal frameworks were constructed using the same working cast and divided into three groups: (1) NS group – consisted of frameworks (n = 6) cast in one piece, which was not sectioned; (2) CS group – consisted of frameworks (n = 6) whose components were joined by conventional soldering; and (3) LW group – consisted of frameworks (n = 6) whose components were joined by laser welding. The control group consisted of six silver-palladium alloy copings, which were not cast, but were screwed to the master cast.

The sectioned components were screwed to the dental abutments in the acrylic resin master cast, tightened to 20 Ncm, and joined together with a chemically activated acrylic resin (Duralay, Reliance Dental Mfg Co, Worth, USA) (Fig. 4).

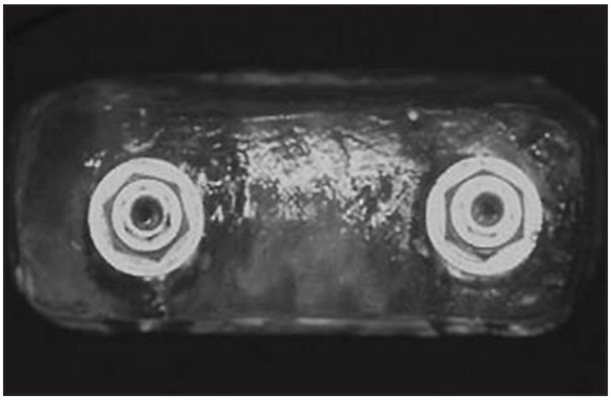

Fig. 1: Upper view of the acrylic resin master cast.

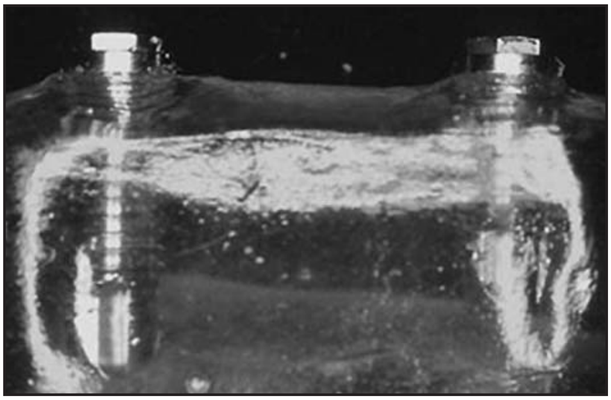

Fig. 2: Front view of the acrylic resin master cast.

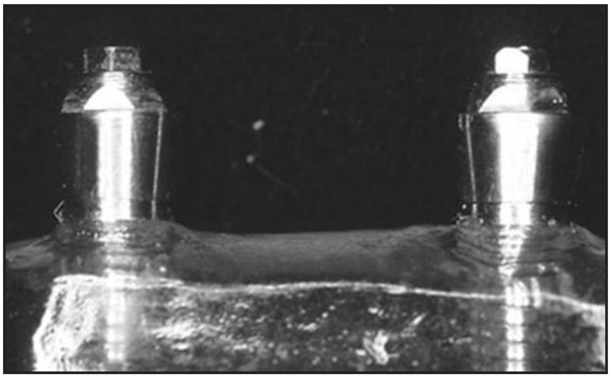

Fig. 3: Dental abutments (Microscone) screwed to the implants.

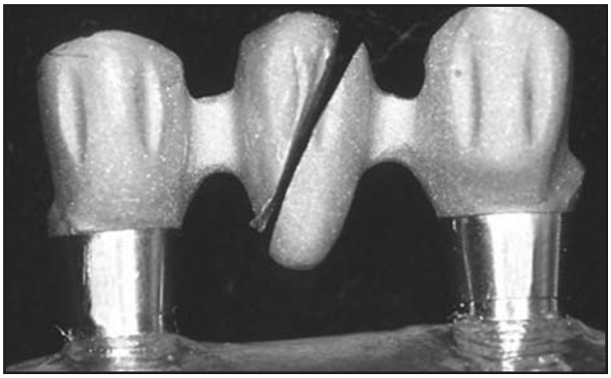

Fig. 4: Sectioned framework component.

The frameworks were sent to the dental laboratory and joined by either conventional soldering or laser welding. Conventional soldering consisted in building a type V dental stone block with replicas of the abutments screwed to the prosthesis framework. A layer of refractory material (G-Cera, Orbit Vest, USA) 3 mm thick was applied to the external surface of the cast. After the refractory material had hardened (approximately 2 hours), the set was placed in an oven at 722°C for 30 minutes. The cooling procedure was carried out for 30 minutes followed by alumina blasting; glass beads were inserted within the empty space created after removal of the acrylic resin. Hot steam was used to remove excess material. The frameworks were placed back in the oven at 790°C for 1 hour. After the sets were removed from the oven, they were soldered with a blowpipe. Welding was performed using a laser welder (DL 2002S, Dentaurum, Germany), following the manufacturer's instructions. The welding site was flushed with argon as shielding gas; the gas nozzle was maintained approximately 5 mm from the object; the laser beam angle was 15°; and approximately the same number of spot-welds were applied on both sides of the component. Infrared laser can generate temperatures high enough to melt the metal at the welding site. In this study, the energy delivered was controlled by two parameters: power and pulse duration of the laser beam. After all frameworks were constructed, each framework was placed on the acrylic resin master cast to measure the fit.

Marginal gap measurement

A protocol was developed for measuring the marginal gaps. Measurements were performed using a measuring microscope (Measurescope, Nikon, Japan) with a 0.001-mm stage micrometer, field of view of 50 x 100 mm, at x30 magnification. The prosthetic fit was assessed at a single point in the middle of the buccal face of the two dental abutments at 4 different time points: time point 1 (T1) – the marginal gap was assessed on coping number 1 when only this coping was screwed to the dental abutment in the master cast and tightened to 20 Ncm; time point 2 (T2) – the marginal gap was assessed on coping number 2 when only coping number 1 was screwed to the abutment and tightened to 20 Ncm; time point 3 (T3) – the marginal gap was assessed on coping number 1 when both copings were screwed to the abutments and tightened to 20 Ncm; and time point 4 (T4) – the marginal gap was assessed on coping number 2 when both copings were screwed to the abutments and tightened to 20 Ncm. The time points are illustrated in Fig. 5 and 6.

RESULTS

Marginal gap measurements obtained for all frameworks in each experimental group at different time points are shown in Tables 1, 2 and 3. The experimental data were statistically analyzed using analysis of variance (ANOVA) for comparison between groups. The values used in the statistical analysis were those shown in Tables 1 to 3 subtracted by the mean marginal gap for the control group (5 µm). Experimental data for the control group are listed in Table 4.

Mean marginal gap and standard deviation (SD) values for the three experimental groups are shown in Table 5. The data in Table 5 were analyzed using ANOVA and results are presented in Table 6.

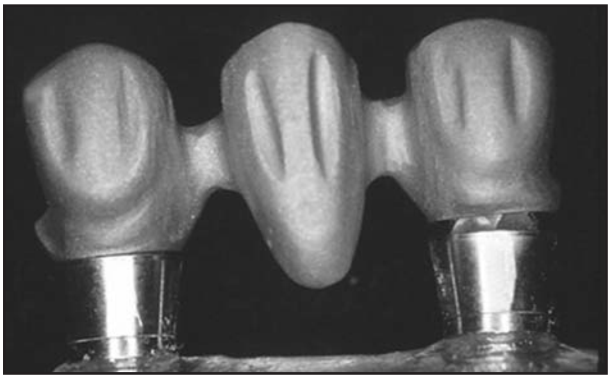

Fig. 5: Marginal gap measurement with only the coping number 1 tightened. Observe the gap in coping number 2

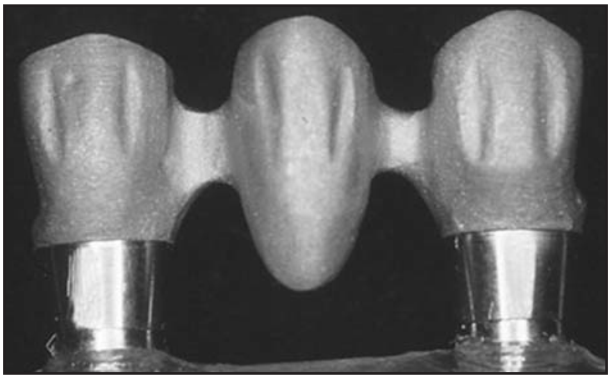

Fig. 6: Marginal gap measurement with both copings tightened. Observe the prosthetic fit in both copings.

Table 1: Marginal gap measurements (in micrometers) for the NS group (frameworks without soldering or welding).

Framework n = 6	T1 – coping 1 (coping 1 tightened)	T2 – coping 2 (coping 1 tightened)	T3 – coping 1 (both copings tightened)	T4 – coping 2 (both copings tightened)
1	11	380	9	40
2	5	610	12	29
3	12	410	15	35
4	9	661	9	51
5	13	599	10	12
6	11	510	15	35

Table 2: Marginal gap measurements (in micrometers) for the conventional soldering group (CS).

Framework n = 6	T1 – coping 1 (coping 1 tightened)	T2 – coping 2 (coping 1 tightened)	T3 – coping 1 (both copings tightened)	T4 – coping 2 (both copings tightened)
1	11	11	10	11
2	12	21	12	11
3	9	32	9	9
4	12	41	12	9
5	11	20	10	12
6	13	11	11	11

Table 3: Marginal gap measurements (in micrometers) for the laser welding group (LW).

Framework n = 6	T1 – coping 1 (coping 1 tightened)	T2 – coping 2 (coping 1 tightened)	T3 – coping 1 (both copings tightened)	T4 – coping 2 (both copings tightened)
1	12	19	10	11
2	13	11	11	9
3	10	90	21	12
4	12	11	5	10
5	12	70	15	10
6	21	49	20	15

Table 4: Marginal gap measurements (in micrometers) for the control group.

Copings (n = 6)	Marginal gap (μm)
1	5
2	5
3	6
4	5
5	6
6	5
Mean	5

Table 5: Mean marginal gap and standard deviation (SD) values (in micrometers) for the three experimental groups at different time points.

Marginal gap (μm)	T1 – only coping 1 tightened			T4 – both copings tightened		
	NS	*CS*	*LW*	*NS*	*CS*	*LW*
Mean	6.67	5.67	8.67	28.67	5.50	6.17
SD	2.80	1.21	6.19	12.92	1.50	2.14

NS, group of frameworks without sectioning and soldering (or welding); CS, conventional soldering group; LW, laser welding group.

Table 6: Comparison of marginal gap measurements between experimental groups.

Comparison	F	p-value	Statistical Significance
T1 – NS x CS x LW	0.88	0.4342	No
T4 - NS x CS x LW	18.08	< 0.0001	Yes

T1, marginal gap assessed on coping 1 when only this coping was tightened; T4, marginal gap assessed on coping 2 when both copings were tightened; NS, group of frameworks without sectioning and soldering (or welding); CS, conventional soldering group; LW, laser welding group. Analysis of variance (ANOVA).

Table 7: Comparison of marginal gap measurements between T1 and T4 for each experimental group.

Group	Test	Test result	p-value	Statistical Significance
NS	Mann-Whitney U test	U=2.5; U'=33.5	0.0108	Yes
CS	Student's t-test	t=0.237	0.8174	No
LW	Mann-Whitney U test	U=23; U'=13	0.4719	No

T1, marginal gap assessed on coping 1 when only this coping was tightened; T4, marginal gap assessed on coping 2 when both copings were tightened; NS, group of frameworks without sectioning and soldering (or welding); CS, conventional soldering group; LW, laser welding group.

Scheffe's test was used for pairwise comparisons of means. A statistical equivalence in marginal gap was found between the CS group (mean, 5.50 μm) and LW group (mean, 6.17 μm) at T4. The results showed that the NS group had a significantly greater marginal gap (mean, 28.67 μm) than other experimental groups ($p<0.01$). These results were confirmed by comparing the mean marginal gap obtained at T1 and T4, using Student's *t*-test for the CS group, and non-parametric Mann-Whitney U test for the NS and LW groups. The latter test was used because of differences in marginal gap between time points in the NS and LW groups. Our results revealed that only the NS group had significant differences in marginal gap between T1 and T4, showing that the marginal gap between the abutment and second coping at T4 (after the prosthesis was attached to both abutments) was greater than the gap between the abutment and first coping at T1 (when the prosthesis was attached only to coping 1). There no significant difference in marginal gap between T1 and T4 for the CS and LW groups, showing that the gap measured on coping 1 at T1 was similar to that measured on coping 2 at T4 in both groups (Table 7).

DISCUSSION

The fit of implant-supported prostheses is a topic that has been discussed extensively. Most studies on oral rehabilitation with osseointegrated implants emphasize the importance of a good fit of the prosthesis to the implants. However, there is no consensus at present as to the acceptable degree of misfit that does not compromise the entire prosthetic restoration. The studies are usually not conclusive regarding the dimension of the marginal gap that would lead to complications in the implant-prosthesis system.

Stress induced by a dental framework upon supporting structures results from a combination of factors. Among these factors, misfit at the gold cylinder-abutment interface appears to be the major factor responsible for increased stress in the implant-prosthesis system. In the present study, reference points for the measurement of prosthetic fit were defined based on a study that measured the misfit at the implant-prosthesis interface[9].

Our results revealed that a precise interface between the metal copings and dental abutments was not achieved even in the control group (individual copings that were not cast together). This is in agreement with some previous studies[10,11], which considered that an absolute passive fit is practically impossible to attain (see Table 4).

Marginal gap measurements (Table 1) indicated that the NS group had poor prosthetic fit at T2 (before the second coping was tightened to the abutment). On the other hand, a significant improvement in prosthetic fit was observed at T4 (after the second coping was tightened to the abutment), increasing prosthetic fit to acceptable levels[3]. However, the tightening of the second screw to close the large marginal gap created at T1 certainly generated stress in the implant-prosthesis system, overloading individual components. This overload often leads to increased stress on the gold screws, resulting in screw loosening or fractures[10].

There seems to be a consensus among contemporary researchers that sectioning and soldering (or welding) are required to reduce the misfit of implant-supported prostheses[12,15]. A cast framework does not accurately fit multiple abutments without sectioning followed by soldering. This was confirmed in the present study; it was observed that the NS group had greater marginal gaps than the CS and LW groups at all time points (Table 5).

Some authors observed that the tightening of the screws (either manual tightening or with a torque wrench to 10 or 20 Ncm) prior to welding had no influence on the vertical fit of implant-supported metal frameworks[19]. Laser welding has proved to be an efficient method to improve the fit of implant-supported prostheses[12,15,20]. It allows the joining of prosthesis components, improves the fit, distributes forces evenly, and minimizes failure of retainers. However, our results did not confirm the advantages of laser welding over conventional soldering, regarding the dimension of marginal gaps between the metal framework and dental abutments. There was no significant difference in marginal gap between the CS and LW groups (Table 6). The equivalence of results between laser welding and conventional soldering may be attributed to the size of the prosthesis. The major difficulty in welding and soldering lay in the large number of points to be joined in long-span prostheses[4]. In this situation, laser welding is much more efficient than soldering.

The results presented in this study are similar to the findings of other studies[4,6,11,12]. There are, however, some relevant points that can be addressed in further studies, including questions regarding the gold screws. Many studies have considered that the gold screws are the components of the implant-prosthesis system subjected to the most immediate consequences of prosthesis misfit[10,11]. A study evaluated the misfit, fracture, and loosening of gold screws of prostheses 5 years in function[11]. The authors concluded that there might be a significant clinical correlation between prosthesis misfit and screw loosening. This conclusion was directly related to the degree of prosthesis misfit, which may lead to mechanical complications, such as screw loosening or fracture. However, the results were not conclusive, because well-fitting prostheses may also have loose or fractured screws. There is no consensus in the literature as to the acceptable degree of misfit, and different torque values have been recommended for different implant-prosthesis systems. It is difficult to achieve precise assessment of the degree of misfit, which could be used to demonstrate the effectiveness of procedures or indicate the need for a change of procedures.

Numerous methods have been described to evaluate the fit of prosthetic frameworks[6,16]; some of them are empirical. Although there are several methods to improve casting accuracy and prosthesis construction, many questions remain regarding the evaluation of the final product and verification of the fit. Some authors used washers to increase the contact area between the gold screw and metal coping[17,18]. Other authors[5] evaluated the stress distribution on screw-retained prostheses and concluded that the marginal gap was the major cause of failure of this type of prosthesis. It was observed that marginal gaps of 30 μm were present on 90% of the surface between the dental abutment and superstructure. Because small gaps are not clinically detectable, prostheses that appear to have a “perfect fit” may be placed under tension during screw tightening. Several methods to improve the fit of implant-supported prostheses have been developed and discussed. It was observed that gaps were present along the entire interface between the gold cylinder and dental abutment[5,17,18]. The stress generated in the implant-prosthesis system appears to decrease when the framework is sectioned and soldered. This is consistent with our results, which showed that marginal gaps at T4 (after the prosthesis was attached to both abutments) were less than 30 μm in the CS and LW groups, but greater than 30 μm in the NS group. However, gap measurements were made at only one point of the interface between the gold cylinder and dental abutment. Moreover, the reference value of 30 μm is empirical and cannot be used as an indicator of passive fit.

Research and clinical practice have demonstrated that the proper fit of implant-supported prostheses is of fundamental importance for successful oral rehabilitation.

Because marginal gaps are of the order of tens of micrometers, the fit was assessed using a measuring microscope. This does not allow prosthetic fit to be assessed in daily clinical practice. Therefore, subjective methods such as x-rays, surveys, tightening torque, visual examination, patient sensitivity and professional experience, among others, are used to achieve a proper prosthetic fit, but these methods may result in erroneous estimates of marginal gap. Our results confirm the findings of previous studies that the sectioning of short-span implant-supported prostheses followed by soldering or welding optimize the prosthetic fit.

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