Systematic Review
Implantandology

Systematic review and meta-analysis of welding procedures in one-piece cast implant-supported frameworks

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Abstract: The objective of this systematic review and meta-analysis was to evaluate the effect of welding techniques on implant-supported prostheses and determine whether they contribute to a better adaptation compared with a one-piece cast. A search was conducted using the PubMed/MEDLINE, Embase, and Cochrane Library databases, and articles published until November 2017 were obtained from these databases. This review followed the PRISMA criteria and is registered on the PROSPERO platform (CRD42017081865). The PICO question was *"Do welding procedures in one-piece cast implant-supported frameworks influence implant/abutment-framework marginal misfits?"* Eleven studies were selected for a qualitative analysis, and seven studies were selected for a quantitative analysis. A total of 189 specimens were fabricated using different materials (cp-Ti, Ni-Cr, Cr-Co, and noble alloys), and welding techniques such as laser welding, conventional welding, tungsten inert gas, and brazing were applied. A vertical marginal misfit was measured using an optical microscope, a stereomicroscope, and/or a scanning electron microscopy. The qualitative analysis in the studies demonstrated a positive effect of the welding techniques on the adaptation of the infrastructures. The meta-analysis confirmed the results ($p < 0.00001$; MD: -36.14; 95%CI: -48.69 to -23.59). Within the limitations of this study and regarding the heterogeneity of the samples, we conclude that the soldering point technique is effective for obtaining relatively low values of marginal misfit, with laser welding as the most effective technique. However, additional studies were recommended due to the heterogeneity of different variables (alloys, connection, and misfit evaluation) in the included studies.

Keywords: Dental Implants; Welding.

Introduction

The accuracy of fitting between a prosthesis and an implant is a prerequisite for the long-term success of implant-supported rehabilitations.[1] Misfits formed at the interface between the implant and the infrastructure transfer stresses to the prosthesis and the peri-implant bone, with consequent adverse biological responses and prosthetic complications.[2,3]

Several fabrication methods of implant frameworks are proposed to minimize distortion, and they consequently reduce the marginal misfit.[4]

However, studies affirm that distortion is inevitable during the fabrication process of frameworks (stone cast, inclusion in coating material, and casting in metallic alloy) since it is inherent to the process.[5,6,7] New technologies, such as CAD/CAM systems, demonstrate substantial accuracy of the pieces that constitute the infrastructures in a one-piece cast,[8,9] and certain manufacturing stages are omitted compared with the conventional technique of lost-wax.[3]

A frequently employed procedure to reduce the framework distortion, which is known as a soldering point, is sectioning with subsequent welding. This procedure was proposed in 1987 as an alternative method for frameworks that were manufactured in a one-piece cast to promote better adaptation between the prosthesis and the implant,[10] which would reduce the residual stress exerted on the prosthesis and the bone.[11] Different welding techniques are applied, such as conventional welding[12] gas-torch brazing, laser welding, and tungsten inert gas (TIG).[13]

Welding is the sectioning and fixation of the parts to be soldered with acrylic resin for the previous one-piece framework; inclusion in the coating set is necessary and enables the removal of acrylic resin and the release of the space to be welded. A gas-torch brazing technique is performed by a metal alloy with a melting point that is lower than that of the base metal at temperatures above 450°C; the addition of molten material supplied by the flame contacts the areas to be welded, which causes their union.[14,15,16]

The tungsten inert gas (TIG) technique enables parts to be bonded by heating the materials through an arc between the non-consumable tungsten electrode and the part. However, the laser welding technique commonly uses a mixture of gas that contains CO2 and yttrium aluminum garnet (YAG) in the solid state. Energy is supplied in the form of an electromagnetic wave that melts the surface that receives the impact, removes a small amount of metal and transfers it to the other surface. Because the energy is applied with substantial force in the region, the use of welding coating is not needed in the laser process, which enables the welding of structures or parts with aesthetic finishes without damaging them.[14,15,16]

Certain studies[6,17,18] affirm that the implementation of a welding technique in an implant-supported framework can reduce misfit between an implant and a prosthesis. However, different studies report the absence of an effect,[11] even a negative effect,[12] on marginal misfit when using the soldering point technique. Therefore, no consensus has been reached regarding a technique that exhibits the best adaptation values.

Thus, this systematic review of the literature intends to evaluate whether the welding technique produces a better adaptation of prosthetic infrastructures than infrastructures manufactured in a one-piece cast. The null hypothesis affirms that no difference exists between two pieces manufactured in a one-piece cast, regarding the marginal misfit, when compared with welding techniques.

Methodology

Protocol register

This systematic review follows the PRISMA criteria[20] in accordance with certain systematic reviews of the literature.[21,22] In addition, the methods applied to conduct the review were recorded on the Prospero registration platform (Prospective Register of Systematic Reviews) (CRD42017081865).

Eligibility criteria

The studies eligible for this systematic review followed the criteria: a) Clinical studies (controlled, randomized, prospective, and/or retrospective studies); b) *in vitro* studies; c) studies that evaluate the vertical marginal misfit; and d) studies published in English.

The exclusion criteria of the studies are listed as follows: a) Clinical cases; b) cases of series; c) *in vivo* studies (animals); and d) reviews.

The formulated PICO question was "*Do welding procedures in one-piece cast implant-supported frameworks influence implant/abutment-framework marginal misfits?*" The population was composed of three-element implant-supported frameworks/or prostheses. Intervention was the realization of the soldering point technique. The comparison consisted of the confection of one-piece casts of implant-supported frameworks/or prostheses. The outcome was evaluated considering the influence of the two techniques in relation to the vertical (μm) marginal misfit of the implant/abutment frameworks.

Search strategy

An electronic search was conducted by two independent researchers (J.M.L.G and C.A.A.L) using PubMed/MEDLINE, Embase, and Cochrane Library databases to obtain articles published until October 2017 following the eligibility criteria. The following keywords were employed: *"soldering and implant supported prostheses OR soldering and framework OR soldering and misfit OR soldering and fit OR soldering and adaptation OR welding and implant supported prostheses OR welding and framework OR welding and misfit OR welding and fit OR welding and adaptation OR one piece cast and implant supported prostheses OR one piece cast and framework OR one piece cast and fit OR one piece cast and misfit OR one piece cast and adaptation"*.

In addition, manual searches of the following journals were conducted with a significant concentration in the area of prosthodontics and implantology: *International Journal of Prosthodontics, Journal of Prosthetic Dentistry, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, International Journal of Oral and Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery, Journal of Oral and Maxillofacial Surgery, Journal of Clinical Periodontology, Journal of Dental Research, Journal of Oral Implantology, Journal of Oral Rehabilitation, Journal of Periodontology, and Periodontology 2000, International Journal of Periodontics and Restorative Dentistry, European Journal of Esthetic Dentistry, and Journal of Prosthodontics.*

During the selection process, studies were conducted to verify whether the information in the title and abstract comply with the eligibility criteria. When the first two researchers disagreed, a third researcher (E.P.P) was consulted, and an agreement was obtained via a consensus meeting.

Data analysis

One author (J.M.L.G) was responsible for collecting relevant information from the included articles, and a second author (C.A.A.L) reviewed all collected information. The data collected from the selected articles consisted of information about the author, study year, study type, number of samples, materials, type of prosthesis, implant system or abutment, welding technique, measurement method, vertical marginal misfit (average/standard deviation) for each evaluated group (one-piece cast and soldering point), conclusions, and effect of welding techniques (negative/none/positive) will be considered for a qualitative analysis.

Risk of bias

The risk of bias for the studies was analyzed using the JBI Critical Appraisal Checklist for Quasi-Experimental Studies (non-randomized experimental studies). JBI provides a critical analysis of the methodological quality of the selected studies. These tools are built into the first JBI System for management, evaluation, and a unified information verification software module (SUMARI; http://joannabriggs.org/sumari.html)[23]. Each study is individually evaluated. JBI provides ten items to be selected based on the characteristics of the studies as follows: "Yes," "No," "Not clear," or "Not applicable". The analysis is conducted via two examiners, and subsequently, a union score of all studies is obtained.

Summary measurements

One researcher (J.M.L.G.) collected relevant data from the articles, which were checked by two other researchers (R.S.C. and H.F.F.O). The meta-analysis was based on an inverse variance (IV) method. A marginal misfit was considered to be the continuous outcome and was evaluated using the mean difference (MD) evaluated by IV with a 95% confidence interval (CI). The MD values were considered significant when $p < 0.05$. For statistically significant ($p < 0.10$) heterogeneity, a random-effects model was used to assess the significance of the treatment effects. When statistically significant heterogeneity was not observed, an analysis was performed using a fixed-effects model. The software Reviewer Manager 5 (Cochrane Group) was used for the meta-analyses.

Additional analysis

The Kappa score was used to calculate the inter-reader agreement during the inclusion process for publication-evaluated databases. Any disagreements were resolved via discussion and consensus among all authors.

Results

Search strategy

The database search selected 1164 studies, including 593 studies in PubMed/MEDLINE, 515 studies in Embase, and 56 studies in the Cochrane Library. All duplicate references were excluded; a total of 1086 articles were selected for the evaluation of titles and abstracts. After a detailed reading of the titles and abstracts and application of the eligibility and exclusion criteria, a total of 27 articles were selected for reading. After reading the articles, 15 articles[1,4,13,10,27,28,29,30,31,32,33,34,35,36,37] were excluded due to the reasons listed in Table 1. Thus, 11 articles were included to analyze the results[2,5-7,11,12,17,18,23,24,25], and 7 studies were selected for a quantitative analysis.[5,6,7,17,23,24,25] Details regarding the search strategy are exemplified in Figure 1. In relation to the inter-reader test, a high degree of agreement among the researchers was observed: PubMed/MEDLINE (*kappa* = 0.87), Embase (*kappa* = 0.90), and Cochrane Library (*kappa* = 1).[38]

Study characteristics

Samples, frameworks, and implants

The characteristics of the included studies are listed in Table 2. A total of 11 studies published between 1996

Table 1. Studies excluded and the reasons for exclusion.

Reasons for Exclusion	References
Insufficient data	Clelland, 1996[24]; Zervas, 1999[25]; Lencioni, 2015[4]
Overdenture and full arch	Alvarez, 2014[26]; Costa, 2004[27]; Riedy, 1997[28]; Rubenstein, 1999[29]; Silva, 2008[10]; Silveira, 2009[30]; Yannikakis, 2013[1]; Sousa, 2008[31]
Studies without comparative group	Barbi, 2012[13]
Fixed partial denture on teeth	Byrne, 1992[32]; Jei, 2014[33]
Clinic cases	Evans, 1997[34]

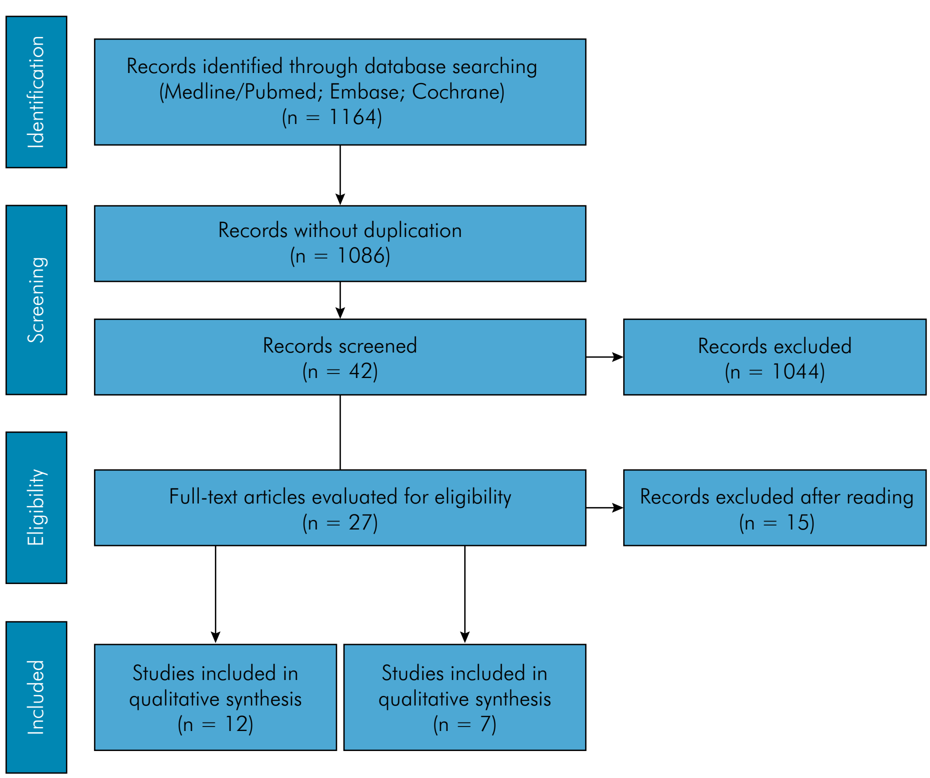

Figure 1. Flowchart detailing the search strategy.

and 2017 were selected.[2, 5,6,7,11,12,17,18,23,24,25] All selected studies were considered *in vitro*, with an evaluation of fixed prostheses that were implant-supported. The studies presented a total of 189 samples (range 3 to 20 samples per group). Nine[5,6,7,11,17,18,23,24,25] of the included studies discussed the measurements of misfit on the interface between the framework and the abutment, and two studies[1,12] discussed the measurements of misfit on the interface between the implant and the frameworks (do not use abutments). Frameworks were constructed using several materials: cp-Ti,[5,6,11,17, 23,25] Ni-Cr,[2,7,12,17,18] Cr-Co,[6,11,17] Ag-Pd.[25]

Different implant systems, such as Neodent,[2,5,18,24,26] Conexão Sistemas de Prótese Ltda.[2,11 12,17,25] were employed. Neves et al.[2] utilized the Biomet 3i system, and Koke et al.[6] used the Friadent GmbH system. Regarding the implant abutment connection, five studies evaluated the external connection,[2,12,11,23,24] four studies evaluated the internal connection using mini pillar conical abutments,[7,17,18,25] and other studies did not report the implant type connection.[5,6]

Soldering point technique

The soldering point technique varied among the selected studies. Most of the included studies evaluated the welding technique regarding laser welding.[5,6,7,11,17,18,23,24,25] Certain studies have reported that the laser power ranged between 390 V/9 ms and 300 V/9 ms,[5,6,18,23,25] while other studies[5,6,25] did not report the laser power used to weld the frameworks. In addition to the laser welding technique, two studies utilized a conventional welding technique,[12,21] one study utilized the TIG technique (36 A/60 ms),[23] and one study utilized a brazing technique (1,200°C–1,315°C).[2]

In addition to the technique type, certain studies compared the effect of a cut in the soldering point and compared the cross-sectional form[7,23] and/or diagonal form,[7,17,18,25] while other studies did not report the soldering point position.[2,5,6,11,12]

Measurement of marginal misfits

To measure misfits, the majority of the studies used an optical microscope.[5,7,17,18,23,25] A stereomicroscope,[2] scanning electron microscopy,[12] digital microscope,[11] and microscope light[6] were also employed. Only the study by Rodrigues et al.[23] evaluated the internal misfit of the frameworks using X-ray microtomography scanning. Measurements at the interface between the implant/abutment were performed differently from the selected studies and are described in Table 2. Furthermore, certain studies[5,7,17,18,25] evaluated the passive fit via the single screw test.

In addition to marginal misfits, further analyses, such as the screw torque test[23] and strain gauge, were conducted in one study.[23]

Outcomes

Among the selected studies, eight studies[5,6,7,17,18,23,24,25] demonstrated the positive effect of welding on the adaptation of fixed implant frameworks. Two studies exhibited a positive effect on only one analyzed group,[2,11] and only one study did not observe improvement when the soldering point was employed.[12]

Meta-analysis

Six studies were not considered in the meta-analysis because they presented insufficient data regarding the vertical marginal misfit described in terms of the mean and standard deviation.[2,11,12,18] Thus, only seven studies were considered for the meta-analysis.[5,6,7,17,23,24,25] In relation to the quantitative analysis, a relatively low value of marginal misfit for groups was observed with the welding technique compared with the one-piece cast technique ($p < 0.00001$; MD: -36.14; 95%CI: -48.69 to -23.59) (Figure 2).

The randomized effect of the analysis was employed due to the high value of heterogeneity of the included studies ($I^2 = 96\%$), with a statistically significant value ($p < 0,00001$). In addition, the asymmetry of the included studies is observed using a funnel plot, which indicates the possibility of publication bias (Figure 3).

Risk of bias

The risk of bias analysis in the studies demonstrated a low risk of bias because the majority of the selected items were evaluated as a "yes," which increases the quality of the included studies. We highlight that the question regarding the follow-up period was evaluated as "not applicable" to the selected studies because all selected studies were considered *in vitro* (Table 3).

Table 2. Characteristics of included studies.

Author/Year	Study design (number of samples)	Metal alloy	Implant connection or abutment/ system	Welding technique	Evaluation method of marginal misfit	Vertical misfit (Mean ± SD) (μm)		Conclusion	Welding technique effects
						One-piece cast	Soldering point		
Rodrigues et al. 2017	G1: OPC (n = 20) G2: LW (n = 10) G3: TIG (n = 10)	cp-Ti	EH; mini abutment; Neodent, Brasil	G1: Laser (390 V/9 ms); G2: TIG (36A/60 ms);	2 points evaluated (B and L); Optical microscope x-ray microtomography.	G1: 203.09 ± 51.11	G2: 42.58 ± 23.58 G3: 52.40 ± 26.46	The TIG technique and Laser welding were effective in the marginal and internal reduction of the misfits.	Positive
Spazzin et al. 2016	G1: OPC (n = 10) G2:FCPA (n = 10) G3: LW (n = 10)	cp-Ti	Multi-unit aburment; Neodent, Brasil	G3: Laser Welding	8 points evalluated; Optical microscope	G1: 111 ± 42.6	G2: 27.4 ± 3.3 G3: 61.1 ± 31.4	LW and FCPA are recommended to improve the fit of implant-supported fixed prostheses.	Positive
Neves et al. 2014	G1: PUN (n = 3) G2: PUC (n = 3) G3: PU3i (n = 3) G4: PUTN (n = 3)	Ni-Cr	EH; analog; Conexão; Neodent; Biomet 3i	Ni-Cr-Co-Mo-, brazing (1200°C-1315°C)	6 pictures on mesial e distal of each abutment; stereomicroscope	% DMV (≤10μm) G1:33.3% G2: 33.3% G3:33.3% G4:83.25%	%DMV (≤10μm) G1:16.6% G2:38.85% G3:27.75% G4:50%	The welding procedure didn't influence an increase marginal misfit in all groups.	None/ Positive
Tiossi et al. 2012	G1: OPC (n = 6) G2: LW DA (n = 6 G3: LW DS (n = 6)	Ni-Cr	Internal Connection; Neodent, Brazil	G2;G3: Laser (300V/9ms)	3 points on B, L, P faces; Optical microscope	Left side screw G1: 16.5 ± 7.55 Right side screw G1: 58.66 ± 14.30	Left side screw G2: 16.27 ± 1.71 G3: 6.43 ± 3.24 Right side screw G2: 39.48 ± 12.03 G3: 23.13 ± 8.24	It increased the accuracy of the adaptation and passivity structures, thus helping to create a successful prosthetic rehabilitation.	Positive
Bianchini et al. 2011	G1: OPC (n = 6) G2: Conventional Soldering (n = 6) G3: LW (n = 6)	Ag-Pd	EH, Conexão, Brazil	G2: Convencional Welding G3: Laser Welding	Optical microscope	G1: 28.67 ± 12.92	G2: 5.50 ± 1.50 G3:6.17 ± 2.14	The results confirm the findings of previous studies that the soldering of the implant-supported prosthesis optimizes the prosthetic adjustment.	Positive
Tiossi et al. 2010	G1: OPC NiCr (n = 6) G2: OPC cp-Ti (n = 6) G3: LW NiCr (n = 6) G4: LW cp-Ti (n = 6)	Ni-CR cp-Ti	Internal Connection; Neodent, Brazil	Laser	3 points on B, L, P face; Optical microscope	G1:11.19 ± 2.54 G2: 27.57 ± 5.06	G3:12.88 ± 2.93 G4:13.77 ± 1.51	The results showed that the welding of the cp Ti structures is able to lower the levels of misfit and also to improve the passivity levels for the same frameworks when compared to one-piece cast frameworks.	Positive

Continue

Continuation

Author/Year	Study design (number of samples)	Metal alloy	Implant connection or abutment/ system	Welding technique	Evaluation method of marginal misfit	Vertical misfit (Mean ± SD) (μm)		Conclusion	Welding technique effects
						One-piece cast	Soldering point		
Aguiar Júnior et al. 2009	G1: OPC (n = 3) G2: LW D(n = 3) G3: LW T (n = 3)	Ni-Cr	Internal Connection; Neodent, Brazil	Laser (300V/9ms)	3 points on B, L, P faces; Optical microscope	G1:11.18 ± 2.54	G2:19.19 ± 11.83 G3:10.08 ± 3.73	The results of this study suggest that the frameworks that were submitted to welding reduce the levels of prosthetic misfit in implant-supported frameworks and also significantly improve the passivity when compared with one-pieces casts frameworks	Positive
Tiossi et al. 2008	G1: OPC (n = 6) G2: Laser Welding (n = 6)	Co-Cr Ni-Cr cpTi	Internal Connection, Conexão, Brazil	Laser Welding	3 points on B, L, P face; Optical microscope	G1: Cr-Co: 54.23 ± 37.10 Ni-Cr:25.00 ± 7.92 cpTi:48.41 ± 26.69	G2: Cr-Co:21.49 ± 9.08 Ni-Cr:13.10 ± 1.81 cpTi:17.70 ± 11.70	Welding of the specimens, followed by laser welding, is a suitable procedure to achieve lower misfit values and promote better passivity.	Positive
Barbosa et al. 2007	G1: Lab1(n = 2) G2: Lab 2 (n = 2) G3: Lab 3 (n = 2)	Ni-Cr	EH; Conexão Sistemas de Prótese, Brazil	Conventional Welding	2 pictures on mesial and distal face; SEM	% DMV (≤10μm) G1:95% G2:70.8% G3:87.5%	% DMV (≤10μm) G1:70.8% G2:70.8% G3:79.1%	The weld increased the degree of misfit of the structure, regardless of the laboratory that did it.	Negative
Castillo et al. 2006	G1-S (n = 10) G1-H (n = 10) G2-S (n = 10) G2-H (n = 10)	cp-Ti Co-Cr	EH; Conexão Sistemas de Prótese, Brazil	Laser (300V/10ms)	12 points; Digital microscope	G1S C1:25.08+6.30 C2:25.99 ± 8.01 C3:24.83 ± 3.73 G1H C1:24.99+4.27 C2:22.80 ± 2.70 C3:25.33 ± 6.90 G2S C1:22.91+3.97 C2:25.33 ± 3.02 C3:24.16 ± 2.58 G2H C1:29.83+7.66 C2:26.74 ± 3.54 C3:27.24 ± 4.96	G1S C1:15.83+4.57 C2:19.49 ± 4.30 C3:15.75 ± 3.60 G1H C1:19.08+6.86 C2:18.99 ± 4.86 C3:16.33 ± 2.86 G2S C1:23.91+4.52 C2:21.41 ± 4.60 C3:22.83 ± 3.10 G2H C1:24.83+6.07 C2:21.07 ± 5.39 C3:19.33 ± 3.12	The marginal fitting values for slotted screws were not different with or without laser welding, but significant differences were found for hexagonal screws in the same conditions.	None/ Positive
Koke et al. 2004	G1: Ti G2: Cr-Co	Cr-Co and cp-Ti	Friadent GmbH, Germany	Laser	8 points; Light microscope	G1: 40 ± 11 G2:72 ± 40	G1 e G2: 17 ± 6	The manufacture of the one-piece casts and then the welding provides a better marginal fit.	Positive

EH: external hexagon; B: buccal face; L: Lingual face; D: distal face; M: mesial face; SEM: scanning electron microscopy.

Study or Subgroup	Welding Technique			One piece casting			Weight	Mean Difference	Year	Mean Difference
	Mean	SD	Total	Mean	SD	Total		IV, Random, 95% CI		IV, Random, 95% CI
Rodrigues et al. [TIG]	52.4	26.46	10	203.09	51.11	20	6.3%	-150.69 [-178.45, -122.93]	2017	
Rodrigues et al. [Laser welding]	42.58	23.58	10	203.09	51.11	20	6.5%	-160.51 [-187.26, -133.76]	2017	
Spazzin et al. [Laser welding]	61.1	31.4	10	111	42.6	10	5.6%	-49.90 [82.70, -17.10]	2016	
Bianchini et al. [Conventional Welding]	5.5	1.5	6	28.67	12.92	6	8.7%	-23.17 [-33.58, -12.76]	2011	
Bianchini et al. [Laser Welding]	6.17	2.14	6	28.67	12.92	6	8.6%	-22.50 [-32.98, -12.02]	2011	
Tiossi et al. [Laser Welding – NiCr]	12.88	2.93	6	11.19	2.54	6	9.1%	1.69 [-1.41, 4.79]	2010	
Tiossi et al. [Laser Welding – cpTi]	13.77	1.51	6	27.57	5.06	5	9.1%	-13.80 [-18.40, -9.20]	2010	
Aguiar Júnior et al. [Laser Welding – Diagonal]	19.19	11.83	3	11.18	2.54	3	8.3%	8.01 [-5.68, 21.70]	2009	
Aguiar Júnior et al. [Laser Welding – Transversal]	10.08	3.73	3	11.18	2.54	3	9.1%	-1.10 [-6.21, 4.01]	2009	
Tiossi et al. [CrCo]	21.49	9.08	6	54.23	37.1	6	6.0%	-32.74 [-63.30, -2.18]	2008	
Tiossi et al. [NiCr]	13.1	1.81	6	25	7.92	6	9.0%	-11.90 [-18.40, -5.40]	2008	
Tiossi et al. [cpTi]	17.7	11.7	6	48.41	26.69	6	7.0%	-30.71 [-54.03, -7.39]	2008	
Koke et al. [Laser Welding]	17	6	10	72	40	10	6.7%	-55.00 [-80.07, -29.93]	2004	
Total (95% CI)			88			107	100.0%	-36.14 [-48.69, -23.59]		

Heterogeneity: $Tau^2 = 445.67$; $Chi^2 = 324.78$, $df = 12$ ($P < 0.00001$); $I^2 = 96\%$
Test for overall effect: $Z = 5.64$ ($p < 0.00001$)

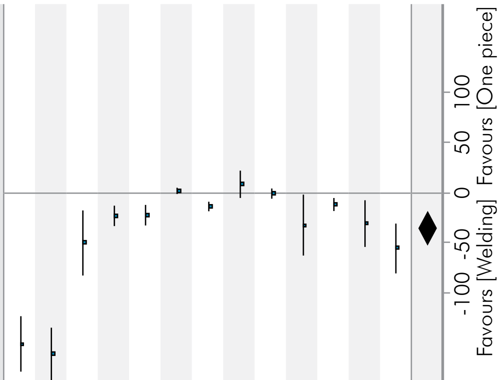

Figure 2. Forest plot. Outcome: Marginal misfit (Soldering point vs. one-piece cast). IV: inverse variance; RE: random effect.

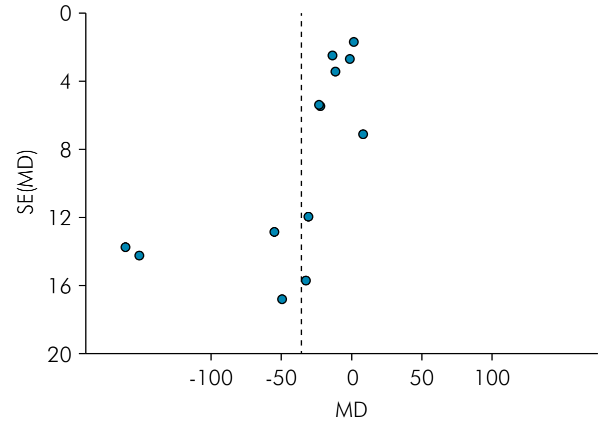

Figure 3. Funnel Plot. Heterogeneity analysis of included studies.

Discussion

The null hypothesis of this study affirms that no difference exists between a one-piece cast and the soldering point technique when a marginal fit was rejected because most of the selected studies presented a favorable characteristic for the soldering point technique and the quantitative results demonstrated a favorable significance for the welding frameworks ($p < 0.00001$; MD: -36.14; 95%CI: -48.69 to -23.59). These data agree with other studies.[3,13,28,38] The misfit improvement in the majority of the frameworks after sectioning and welding may be related to the fact that this technique enables a reduction of distortions generated by the one-piece casting technique, which is caused by clinical and laboratorial steps, such as waxing, coating, and impression.[24,39,40]

Most studies that observed favorable differences regarding the welding technique were conducted using the laser welding technique.[5,6,7,18,23,25] Welding using the laser welding technique has advantages, such as easy application.[5] Compared with the TIG technique[24] or conventional technique,[24] a laser has the advantage of using a minimal portion of the framework at the welding moment, which promotes a significant mechanical longevity of the framework.[3]

Further, two selected studies[23,24] evaluated the laser welding technique and other methods of welding compared with a one-piece cast. In the study by Rodrigues et al.,[23] the misfit values after TIG welding (52.4 µm) and laser welding (42.58 µm) were similar

Table 3. Risk of bias – JBI critical appraisal checklist for quase-experimental studies (non-randomized experimental studies).

Questions- JBI Critical appraisal checklist		Revisor 1				Revisor 2			
		Yes	No	Not clear	NR	Yes	No	Not clear	NR
1	Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	11				11			
2	Were the participants included in any comparisons similar?	11				11			
3	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	9	2			9	2		
4	Was there a control group?	9	2			9	2		
5	Were there multiple measurements of the outcome both pre and post the intervention/exposure?	11				11			
6	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?				11				11
7	Were the outcomes of participants included in any comparisons measured in the same way?	11				11			
8	Were outcomes measured in a reliable way?	11				11			
9	Was appropriate statistical analysis used?	9	2			9	2		

with respect to soldering point techniques. Thus, the welding method does not seem to exhibit a considerable effect on the values of vertical misfit since any method will decrease the misfit compared with a one-piece cast.

A single study among the selected[12] few studies reported the negative effect of the conventional welding technique.[12] In this study, misfit values ≤ 10 μm occurred on an average of 84.43% (70.8%–95%) of the frameworks manufactured in a one-piece cast and averaged 73.56% (70.8%–79.1%) for soldering point frameworks. A justification of these results by the authors is that conventional welding may cause distortions during manufacturing, which increases the misfit levels. However, another study[24] observed a positive effect of the conventional welding technique compared with the one-piece cast technique.[24] The justification is the use of noble alloys, where the material experiences less distortion in one-piece cast frameworks and improves when the soldering point technique is used.[41] Other studies included in this review[6,7,11,17,18,24,26] evaluated non-noble alloys (Ni-Cr, Cr-Co, cpTi) and opted for the use of a laser welding technique to obtain better precision when adapted.

Moreover, certain studies have not verified the effect of the welding technique compared with the one-piece cast.[2,11] In the study conducted by Neves et al.[2], the absence of a difference in the brazing type compared with one-piece casting may be related to the brazing technique, which is executed to construct the framework[13,40] and enables considerable distortion possibilities in the same manner as the one-piece cast confection. Castilho et al.[11] report that this finding may be related to the effect of the different screws with respect to the type of cylinder. The screws with grooves in this study are composed of gold, with a high elastic modulus and consequent deformation of their threads at the moment of load application, which may have hindered a better fit of the implant infrastructure.[11,23]

The cut type used for welding is another factor that can affect the results. Certain studies conducted the cutting of the soldering point in diagonal and transverse forms[7,25] and report that a diagonal cut will affect a relatively small amount of material in the region to be welded, which produces relatively low structure distortions when the metal undergoes cold contractions.

The studies selected in this review observed averages for framework misfits manufactured in a one-piece cast that varied in the range 11.18–203 μm. For frameworks manufactured via welding, the values were in the range 10.8–61.1 μm. Therefore, the lowest values observed in the infrastructures manufactured via the soldering point technique were highlighted, which indicates its benefit regarding the marginal adaptation of fixed implant prosthesis frameworks.

The results observed in this systematic review should be interpreted with caution, because a range of factors that can affect the final results of the work were observed. A high heterogeneity in the meta-analysis may be justified because the data are related to *in vitro* studies; a lack of standardization due to the included studies may affect the increase in this pattern. In addition, the studies indicated limitations regarding the standardization of the techniques used to construct the frameworks in a one-piece cast and the soldering point technique. Moreover, the method of evaluation of the marginal misfit varied between the equipment and the evaluated points. Regarding the framework size, no standardization existed, which influences the effectiveness of the welding.[24]

Within the observed limitations, this systematic review of *in vitro* studies attempted to evaluate the marginal misfit of the fixed prostheses with implanted-supported frameworks manufactured in a one-piece cast compared with welding techniques, which indicated better results regarding the vertical misfit for frameworks manufactured using the welding technique. However, additional studies are required to evaluate the biomechanical and biological behaviors of these frameworks, as well as the effect of the soldering point on the adaptation of implanted-supported prostheses.

Conclusions

Within the limitations of this study and regarding the heterogeneity of the samples, we can conclude that the soldering point technique is effective for obtaining relatively low values of marginal misfit, with laser welding as the most effective technique. However, additional studies are recommended due to the heterogeneity of different variables (alloys, connection, and misfit evaluation) in the included studies.

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