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REVIEW ARTICLE

Steel drills versus zirconia drills on heat generation at the surgical site of dental implants: A systematic review and meta-analysis

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KEYWORDS

Ceramics;
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Hot Temperature;
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Abstract *Objective:* The aim was to evaluate the difference in the heat generated between zirconia (Zr) and steel (SS) drills, during implant site preparation.

Material and methods: This systematic review followed the PRISMA methodology criteria and used the JBI Critical Assessment Guidelines for Quasi-Experimental Studies for quality assessment. The electronic search was conducted by using the PubMed/MEDLINE, Embase, and Cochrane Library databases to January 2023. The formulated population, intervention, comparison, outcome (PICO) question was "Do zirconia drills generate less heat than steel drills during implant site preparation?". The meta-analysis was based on an inverse variance (IV) method.

Results: This review included 10 studies in vitro that used zirconia drills compared to steel drills with or without coatings. The meta-analysis indicated a significant difference between Zr drills and SS drills, with a lower bone temperature variation with Zr drills.

Conclusions: Despite the limitations of this review, it was concluded that Zr drills had significantly less temperature variation than SS drills.

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Contents

1. Introduction

The longevity of dental implants depends largely on obtaining adequate bone healing with the establishment of osseointegration (Albrektsson et al., 1981; Branemark et al., 2001). The trauma caused by drills during implant site preparation and the increase in heat induction during the surgical process of implant installation can compromise bone tissue repair (Eriksson et al., 1984). In addition, it can cause the inhibition of bone tissue regeneration, uncontrolled local inflammation, fibrosis formation, osteocyte degeneration, increased osteoclastic activity, and the development of a thick layer of necrotic tissue (Benington et al., 2001; Harris et al., 2001; Sener et al., 2009; Strbac et al., 2014). In this sense, minimal bone damage during the preparation of the implant site is essential for its higher success rates (Benington et al., 2001; Strbac et al., 2014).

The heat induced during implant site preparation procedures is related to the thickness of the cortical bone, the use of irrigation, pressure exerted, the duration and depth of the drilling, rotation velocity and movement of the drill, the length and diameter of the drill, and the drill design and material type (Chacon et al., 2006; Cordioli et al., 1997; Ercoli et al., 2004; Eriksson et al., 1983; Kim et al., 2010; Oh et al., 2011; Sharawy et al., 2002; Sumer et al., 2011; Yacker et al., 1996). In addition, the repeated use of drills is associated with their superficial wear and decreased cutting efficiency, resulting in increased temperatures and the possible release of contaminants at the implant site (Delgado-Ruiz et al., 2018; Möhlhenrich et al., 2015; Queiroz et al., 2008; Scarano et al., 2020). These disadvantages are also enhanced by the disinfection cycles of the drills, which cause greater resistance to rotation, reduced cutting power, and surface corrosion (Carvalho et al., 2011; Chacon et al., 2006).

Currently, commercially available implant drills are made of stainless steel (SS) alloys with or without coatings, such as titanium nitride (TiN) or tungsten carbide (WC) (Koo et al., 2015). These coatings were developed to improve the cutting efficiency of drills (Koo et al., 2015). Recently, there has been an increase in the use of zirconia (Zr) oxide-based drills (Sumer et al., 2011). These drills are mainly composed of 80% zirconia oxide and 20% alumina oxide, exhibiting biocompatibility, stability, low thermal conductivity, greater resistance to fractures and wear, exemption from corrosive processes, and an elasticity module similar to that of steel (Bayerlein et al., 2006; Scarano et al., 2007). Thus, ceramic drills are expected to be more advantageous than steel drills during the preparation of the implant site (Koo et al., 2015). However, there is still no consensus in the literature on the superiority of Zr drills compared to SS drills (Koo et al., 2015; Scarano et al., 2020).

In a systematic review by Mishra & Chowdhary, 2014, several factors that influence heat generation during implant drilling implant site preparation were evaluated, however, there are no systematic reviews that evaluated the type of drill material, which may be influence factor. Thus, this systematic review of literature evaluated the difference in the heat generated between Zr and SS drills, during implant site preparation. The null hypothesis states that there is no difference between zirconia drills and steel drills in relation to bone temperature variation.

2. Materials and methods

2.1. Protocol

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology criteria (PRISMA 2020 checklist supplementary material) in accordance with certain systematic literature reviews (Batista et al., 2022; Bento et al., 2023; Moher et al., 2009;).

2.2. Eligibility criteria

The studies eligible for this systematic review were in vitro studies, studies comparing thermal changes between zirconia drills with steel and/or steel drills coated with TiN or WC, drills sanitized for each bone osteotomy cycle and studies carried out with the irrigation process, and published in English. Exclusion criteria were clinical cases, serial cases, in vivo studies, studies without thermal comparison, and not using specific drills for the surgical site of the implant.

2.3. Focused question

The formulated population, intervention, comparison, outcome (PICO) question was "Do zirconia drills generate less heat than steel drills during implant site preparation?". The population was composed of dental implants installed in bone specimen. The intervention was the use of zirconia drills in the preparation of the implant site. The comparison consisted of using steel drills with or without coating to prepare the implant site. The outcome is the thermal variation.

2.4. Search strategy

An electronic search was conducted by 2 independent researchers (V.A.A.B., C.D.D.R.D.R.) who, following the eligibility criteria, searched the PubMed/MEDLINE, Embase, and Cochrane Library databases to obtain articles published until January 2023. The following keywords were used: "(dental implants OR dental implant OR implant material) AND (dental implant drill OR ceramic implant drill OR zirconia implant drill) AND (transition temperature OR heat generation OR bone temperature OR intrabony temperature)". No filters and/or limits of the database were used in the searches. In addition, manual searches were performed in the reference list of included articles and in the non-peer-reviewed literature, using the databases OpenGrey (https://www.opengrey.eu) e Grey Literature Report (https://www.greylit.org/about).

2.5. Selection process

After the systematic literature search, all identified citations were loaded into the Endnote X9 software program (https://endnote.com/) and duplicates were removed. The titles and abstracts were then selected by 2 independent reviewers (V.A.A.B., C.D.D.R.D.R.) to evaluate according to the eligibility criteria. When the first 2 researchers disagreed, a third (E.P.P.) was consulted, and an agreement was obtained via consensus.

2.6. Data collection process

The full text of the potentially eligible studies was retrieved and evaluated in detail by 2 independent reviewers. One author (V.A.A.B.) was responsible for extracting data from the included articles (qualitative or quantitative), and other two authors (J.P.J.O.L., D.M.S.) reviewed all collected information. The data collected from the selected articles consisted of information about the author, year of study, number of specimen, materials (type of drill and type of bone), type of analysis (bone temperature and/or surface wear of the drills) and the conclusions and the effects (Positive/None/Negative) that will be considered for a qualitative analysis, this criterion being adopted by the degree of significance found in the result of each study.

2.7. Bibliometric analysis

The risk of bias for vitro studies was analyzed by 2 investigators (J.P.J.O.L., D.M.S.) using the JBI Critical Assessment Checklist for Quasi-Experimental Studies (non-randomized experimental studies). The JBI provides a critical analysis of the methodological quality of the selected studies. These tools are incorporated into the first JBI system for management, evaluation and a unified information verification software module (SUMARI; https://joannabriggs.org/sumari.html). Each study is assessed individually. The JBI included 9 items to be considered based on the characteristics of the studies as follows: Yes, No, Not clear, or Not applicable. The analysis was performed by 2 examiners and, subsequently, a score was obtained by combining all studies Godfrey et al. (2010).

2.8. Summary measurements

One researcher (V.A.A.B.) collected relevant data from the articles, which were verified by two other researchers (J.M.L.G., M.C.G.). The meta-analysis was based on an inverse variance (IV) method. The thermal variation was considered the continuous outcome and was evaluated by the mean difference (MD) and evaluated by IV with a 95% confidence interval (CI). The MD values were considered significant when $p < 0.05$. For statistically significant heterogeneity ($p < 0.10$), a random effects model was used to assess the significance of treatment effects. Where no significant heterogeneity was found, an analysis was performed using a fixed effects model. Reviewer Manager 5.4 software (Cochrane Group) was used for the meta-analysis.

2.9. 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 by discussion and consensus among all authors.

3. Results

3.1. Search strategy

The database search identified 250 studies, including 151 studies in PubMed/MEDLINE, 92 studies in Embase, and 7 studies in the Cochrane Library. All duplicate references were excluded, and 158 articles were selected for the evaluation of titles and abstracts. After detailed reading of the titles and abstracts, 13 articles were selected to undergo the eligibility and exclusion criteria; ultimately, three articles (Batista et al., 2014; Akiba et al., 2016; Koopaie et al., 2019) were excluded from the study for the reasons listed in Table 1. Details of the search strategy are shown in Fig. 1. The Kappa test revealed a high level of agreement between the examiners (0.85—1.00).

3.2. Study characteristics

Ten studies published between 2011 and 2020 were selected, all of which were considered in vitro (Er et al., 2018; Harder et al., 2013; Hochscheidt et al., 2017; Koo et al., 2015; Moshiri et al., 2013; Oliveira et al., 2012; Pires et al., 2012; Scarano et al., 2020a; Scarano et al., 2020b; Sumer et al., 2011). Nine studies focused on comparing the Zr drill with the SS drill and one study (Koo et al., 2015) compared the Zr drill with the coated SS drill (WC and TiN). The zirconia drills recorded temperature variation between 21.81 °C and 49.3 °C while the SS drills between 21.14 °C and 42.45 °C. The characteristics of the included studies are summarized in Table 2.

3.3. Outcomes

Among the selected studies, three studies (Oliveira et al., 2012; Scarano et al., 2020a; Scarano et al., 2020b) demonstrated a positive effect of using Zr drills when compared to SS drills regarding the increase in temperature during bone preparation. Five studies (Harder et al., 2013; Koo et al., 2015; Moshiri et al., 2013; Pires et al., 2012; Sumer et al., 2011) did not show any difference between Zr and SS drills, and two studies (Er et al., 2018; Hochscheidt et al., 2017) observed a negative performance of Zr drills when compared to SS drills. Table 2.

Table 1 Studies and the reasons for exclusion.

REASONS FOR EXCLUSION	REFERENCES
Studies without comparative group	Batista Mendes et al, 2014
In vivo study	Akiba et al, 2016
Without use implant drills	Koopaie et al, 2019

3.4. Risk of bias

The JBI Critical Assessment Checklist for non-randomized experimental studies indicated a low risk of bias, because most of the selected items were evaluated as a yes, with all studies having above 60% of the criteria. Table 3 shows the results of the evaluation of the studies included in the systematic review.

3.5. Meta-analysis

Six studies (Er et al., 2018; Harder et al., 2013; Hochscheidt et al., 2017; Moshiri et al., 2013; Oliveira et al., 2012; Sumer et al., 2011;) were not considered in the meta-analysis because they presented insufficient data in terms of mean and standard deviation in relation to temperature variation. Thus, four studies (Koo et al., 2015; Pires et al., 2012; Scarano et al., 2020a; Scarano et al., 2020b;) were considered for the meta-analysis, as two studies (Scarano et al., 2020a; Scarano et al., 2020b) presented a positive effect of Zr drills and two studies (Koo et al., 2015; Pires et al., 2012) did not present any differences between Zr and SS drills. The meta-analysis indicated a significant difference between Zr drills and steel drills, with a lower bone temperature variation with Zr drills ($P = 0.01$; MD: -0.50; 95% CI: -0.90 and -0.11). In addition, low heterogeneity was observed ($I2 = 0\%$, $P > 0.10$); therefore, the fixed-effects model was employed (Fig. 2). The symmetry of the included studies was observed through the funnel graph, indicating a probable absence of publication bias (Fig. 3).

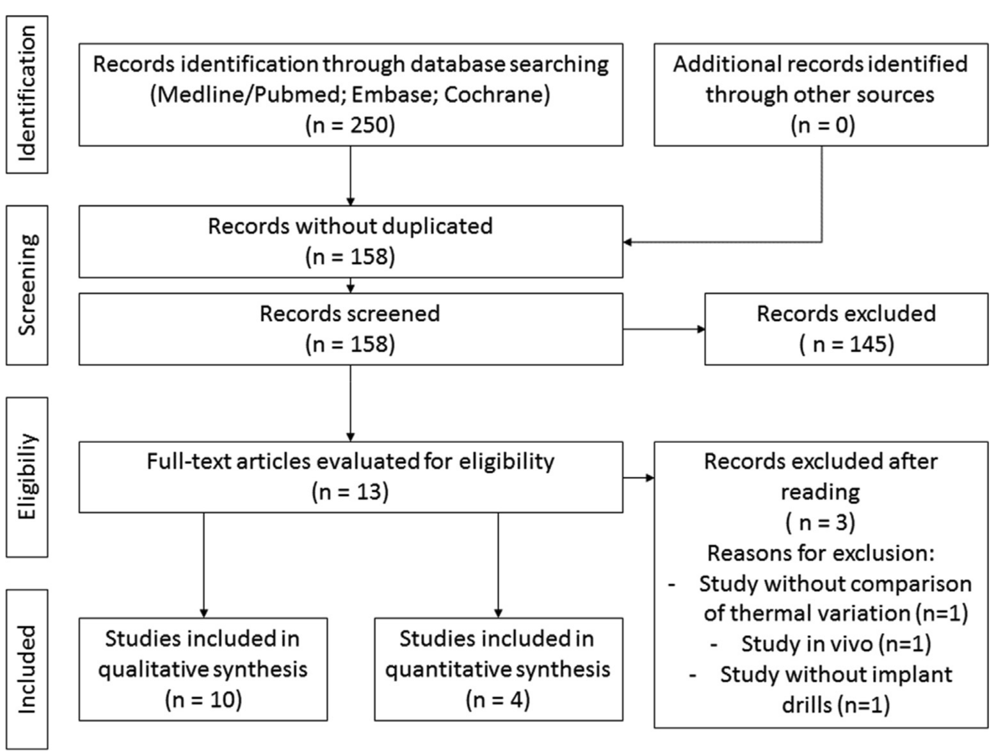

Fig. 1 Flowchart detailing the search strategy.

Table 2 Characteristics of included studies.

AUTHOR / YEAR	NUMBER OF SPECIMEN	TYPE OF ANALYSIS	TYPE OF BONE / TYPE OF DRILL	TECHNICS	OSTEOTOMY CYCLES	TEMPERATURE (°C)		CONCLUSION	EFFECTS
						STEEL	ZIRCONIA		
Scarano et al. 2020a	12	Infrared thermography	Bovine ribs / steel (SS) and zirconia (Zr)	P: 10 mm V: 800 rpm	20	SS0: 38.92 ± 1.13	Zr0: 38.21 ± 1.01	Zr drills showed a lower temperature difference than SS drills	Positive
Scarano et al. 2020b	60	Infrared thermography	Bovine ribs / steel (SS) and zirconia (Zr)	P: 10 mm V: 800 rpm	10; 20; 40; 90; 120	SS10: 39.55 ± 0.98 SS20: 39.97 ± 0.92 SS40: 40.06 ± 1.26 SS90: 41.37 ± 1.81 SS120:42.45 ± 1.70	Zr10: 38.70 ± 0.83 Zr20: 38.90 ± 1.36 Zr40: 39.55 ± 1.79 Zr90: 40.43 ± 1.82 Zr120:40.80 ± 0.85	Zr drills showed a significantly lower temperature difference than SS drills	Positive
Nilay Er et al. 2018	20	Thermocouple	Bovine femur / steel (SS) and zirconia (Zr)	P: 10 mm V: 2000 rpm	1; 25; 50	SS1: 29.1 SS25: 32.4 SS50: 35.6	Zr1: 34.2 Zr25: 44.2 Zr50: 49.3	SS drills and coated SS drills performed better than Zr drills	Negative
Hochscheidt et al. 2017	54	Thermocouple	Bovine ribs / steel (SS) and zirconia (Zr)	P: 5 mm e 13 mm V: 800 rpm	50;	SS5(2): 21.98SS5(2/3) : 21.69SS5(3) : 21.30SS13(2) : 21.33SS13(2/3) : 21.14SS13(3) : 21.07	Zr5(2): 22.00Zr5(2/3) : 21.90Zr5(3) : 21.96Zr13(2) : 21.99Zr13(2/3) : 21.81Zr13(3) : 22.01	SS drills showed a statistically lower temperature difference than Zr drills	Negative
Ki-Tae Koo et al. 2015	12	Thermocouple	Bovine scapula / zirconia (Zr), titanium nitride (TiN) and tungsten carbide (WC)	P: 11 mm V: 3000 rpm	20	TiN(4.2): 32.2 ± 0.8	WC(4.3): 31.1 ± 1.4	Zr(4.2): 32.1 ± 3.4 No significant temperature difference was found between drill types and design	None / Positive
Moshiri et al. 2013	NR	Thermocouple	Bovine femur / steel (SS) and zirconia (Zr)	P: 3 mm; 6 mm e 9 mm V: 1500 rpm	NR	SS3(4.2): 32.2SS6(4.2) : 33.2SS9(4.2) : 32.6SS3(4.3) : 32.1SS6(4.3) : 32.2SS9(4.3) : 31.9	Zr3(4.3): 32.9Zr6(4.3) : 33.3Zr9(4.3) : 32.6	No significant difference in temperature was found related to drill type, design and depth	None / Positive
Harder et al. 2013	NR	Thermocouple	Bovine ribs / steel (SS) and zirconia (Zr)	P: 4 mm; 8 mm e 12 mm V: 1200 rpm	NR	SS4: 3.9 ± 1.8 SS8: 2.8 ± 1.5 SS12: 3.1 ± 1.4	Zr4: 3.7 ± 1.3 Zr8: 2.7 ± 1.0 Zr12: 2.6 ± 1.3	There were no significant differences in heat generation between types of drills	None / Positive
Pires et al. 2012	20	Infrared thermography	Swine ribs / steel (SS) and zirconia (Zr)	P: 10 mm; V: 800 rpm	80	SS80: 32.54 ± 0.13	Zr80: 32.49 ± 0.10	No significant difference was found between temperature and between drill types	None / Positive

(*continued on next page*)

Table 2 (*continued*)

AUTHOR / YEAR	NUMBER OF SPECIMEN	TYPE OF ANALYSIS	TYPE OF BONE / TYPE OF DRILL	TECHNICS	OSTEOTOMY CYCLES	TEMPERATURE (°C)		CONCLUSION	EFFECTS
						STEEL	ZIRCONIA		
Oliveira et al. 2012	NR	Thermocouple	Bovine ribs / steel (SS) and zirconia (Zr)	P: 8 mm e 10 mm V: 800 rpm	50	SS8: 1.04 ± 0.8SS (10) : 2.24 ± 1.1	Zr8: 0.79 ± 0.7Zr (10) : 1.90 ± 1.2	SS drills had a significant increase in temperature compared to Zr drills	Positive
Sumer et al. 2011	NR	Thermocouple	Bovine femur / steel (SS) and zirconia (Zr)	P: 3 mm; 6 mm e 9 mm V: 1500 rpm	50	SS3: 32.15 SS6: 35.94 SS9: 37.05	Zr3: 34.49 Zr6: 36.73 Zr9: 36.52	No significant temperature difference was found related to the type of drill and depth	None / Positive

P = drilling depth; V = drilling speed; NR = Not Reported.

SS0 = new steel drills without disinfection; SS1 = steel drills in one cycle; SS10 = steel drills in ten cycles; SS20 = steel drills in twenty cycles; SS25 = steel drills in twenty-five cycles; SS40 = steel drills in forty cycles; SS50 = steel drills in fifty cycles; SS80 = steel drills in eighty cycles; SS90 = steel drills in ninety cycles; SS120 = steel drills in one hundred and twenty cycles; SS5 (2) = steel drills 2 mm in diameter at 5 mm depth; SS5 (2/3) = steel drills 2 / 3 mm in diameter at 5 mm depth; SS5 (3) = steel drills 3 mm in diameter at 5 mm depth; SS13 (2) = steel drills 2 mm in diameter at 13 mm deep; SS13 (2/3) = 2 / 3 mm diameter steel drills at 13 mm depth; SS13 (3) = steel drills 3 mm in diameter at 13 mm deep; TiN (4.2) = steel drills coated with 4.2 mm diameter titanium nitride; WC (4.3) = steel drills coated with 4.3 mm diameter tungsten carbide; SS3 (4.2) = steel drills of 4.2 mm in diameter at a depth of 3 mm; SS6 (4.2) = steel drills of 4.2 mm in diameter at a depth of 6 mm; SS9 (4.2) = steel drills with a diameter of 4.2 mm at a depth of 9 mm; SS3 (4.3) = steel drills of 4.3 mm in diameter at a depth of 3 mm; SS6 (4.3) = steel drills of 4.3 mm in diameter at a depth of 6 mm; SS9 (4.3) = steel drills of 4.3 mm in diameter at a depth of 9 mm; SS4 = steel drills at a depth of 4 mm; SS6 = steel drills at a depth of 6 mm; SS8 = steel drills at 8 mm depth; SS9 = steel drills at 9 mm depth; SS (10) = steel drills at a depth of 10 mm; SS12 = steel drills at a depth of 12 mm.

Zr0 = new zirconia drills without disinfection; Zr1 = zirconia drills in one cycle; Zr10 = zirconia drills in ten cycles; Zr20 = zirconia drills in twenty cycles; Zr25 = zirconia drills in twenty-five cycles; Zr40 = zirconia drills in forty cycles; Zr50 = zirconia drills in fifty cycles; Zr80 = zirconia drills in eighty cycles; Zr90 = zirconia drills in ninety cycles; Zr120 = zirconia drills in one hundred and twenty cycles; Zr5 (2) = 2 mm diameter zirconia drills at 5 mm depth; Zr5 (2/3) = 2 / 3 mm diameter zirconia drills at 5 mm depth; Zr5 (3) = 3 mm diameter zirconia drills at 5 mm depth; Zr13 (2) = zirconia drills 2 mm in diameter and 13 mm deep; Zr13 (2/3) = 2 / 3 mm diameter zirconia drills at 13 mm depth; Zr13 (3) = 3 mm diameter zirconia drills in 13 mm depth; Zr (4.2) = 4.2 mm diameter zirconia drills. Zr3 (4.3) = 4.3 mm diameter zirconia drills at a depth of 3 mm; Zr6 (4.3) = 4.3 mm diameter zirconia drills at a depth of 6 mm; Zr9 (4.3) = 4.3 mm diameter zirconia drills at 9 mm depth; Zr3 = zirconia drills at a depth of 3 mm; Zr4 = zirconia drills at a depth of 4 mm; Zr6 = zirconia drill at a depth of 6 mm; Zr8 = zirconia drill at a depth of 8 mm; Zr9 = zirconia drill at a depth of 9 mm; Zr (10) = zirconia drills at a depth of 10 mm; Zr12 = zirconia drill at a depth of 12 mm.

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

STUDY	q1	q2	q3	q4	q5	q6	q7	q8	q9
Scarano et al. (2020a)	**Y**	**Y**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**Y**
Scarano et al. (2020b)	**Y**	**N**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**N**
Nilay Er et al. (2018)	**Y**	**U**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**U**
Hochscheidt et al. (2017)	**Y**	**Y**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**Y**
Ki-Tae Koo et al. (2015)	**Y**	**N**	**Y**	**N**	**Y**	**N/A**	**Y**	**Y**	**N**
Moshiri et al. (2013)	**Y**	**Y**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**Y**
Harder et al. (2013)	**Y**	**Y**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**Y**
Pires et al. (2012)	**Y**	**Y**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**Y**
Oliveira et al. (2012)	**Y**	**U**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**U**
Sumer et al. (2011)	**Y**	**Y**	**Y**	**Y**	**Y**	**N/A**	**Y**	**Y**	**Y**
%TOTAL	**100**	**60**	**100**	**90**	**100**	**00**	**100**	**100**	**60**

Y = Yes, **N** = No, **U** = No Clear, **N/A** = Not Applicable; **Q1** = Is it clear in the study what is the 'cause' and what is the 'effect' (that is, there is no confusion about which variable comes first)?; **Q2** = Were the participants included in comparisons similar?; **Q3** = Were the participants included in comparisons that received similar treatment/care, other than the exposure or intervention of interest?; **Q4** = Was there a control group?; **Q5** = Were there multiple measures of the outcome both pre and post the intervention/exposure?; **Q6** = Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?; **Q7** = Were the outcomes of participants included in any comparisons measured in the same way?; **Q8** = Were outcomes measured in a reliable way?; **Q9** = Was appropriate statistical analysis used?.

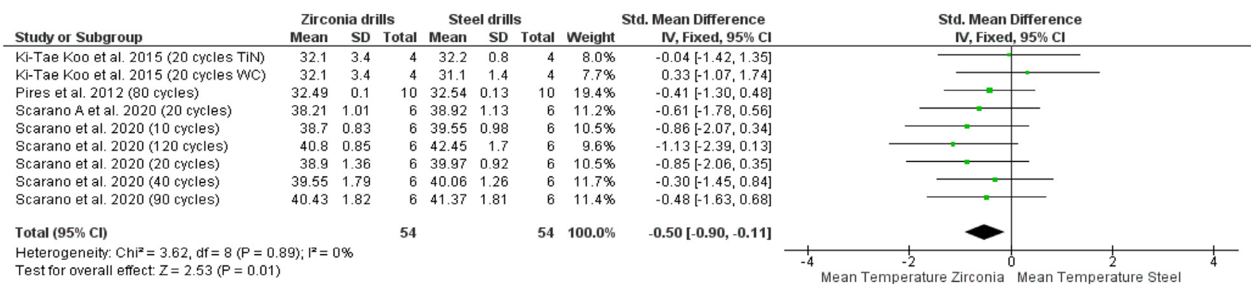

Fig. 2 Forest plot. Outcome: Bone temperature variation ° C (zirconia drills vs steel drills). IV: inverse variance; FE: fixed.

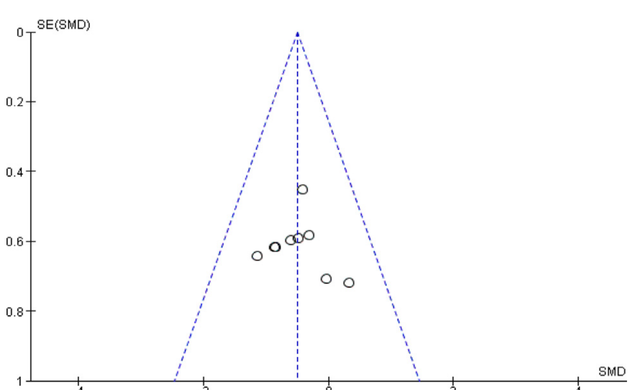

Fig. 3 Funnel Plot. Heterogeneity analysis of included studies.

4. Discussion

This systematic review and meta-analysis was performed to analyze the results of bone temperature variations when using Zr drills compared to steel drills during the preparation of the implant site. The results indicated a significant difference between the Zr drills and the steel drills, presenting less heating when using the Zr drills; therefore, the null hypothesis of this systematic review and meta-analysis was rejected. However, this result may have been influenced by methodological differences between studies and by the inability to include all studies in the meta-analysis.

The studies in this systematic review used different methods to measure the temperature generated during implant site preparation. One method used was thermocouple measurement, which is well-documented in the literature (Chacon. Et al., 2006; Harder et al., 2013) However, it has its limitations, as it is able to provide information only on the walls next to the drill and not on the interface between the drill and the bone (Cordioli et al., 1997; Hochscheidt et al., 2017). Another method used was infrared thermography. This measurement method has the advantage of providing information about the temperature changes in the rotary drill itself (Scarano et al., 2020a). Harder et al., 2018 compared the ability of thermocouples and infrared thermography to detect changes in intraosseous temperatures during the preparation of the dental implant site. They concluded that infrared thermography can reflect changes in intraosseous temperatures more accurately than thermocouples can. Among the four studies selected for the meta-analysis of this systematic review, three used infrared thermography.

One of the factors that influence heat induction during drilling is the cutting power of the drill, which depends on the type of material and design (Möhlhenrich et al., 2015). Thus, the difference found in the meta-analysis of this review can be justified by the physical properties of Zr, such as low thermal conductivity, durability, and greater resistance (Bayerlein et al., 2006; Scarano et al., 2007). In the study by Akiba et al., 2017 after the drilling process, the Zr drills had sharper cutting edges, while the SS drills had greater damage. In addition, Zr drills produced a smoother and flatter bone surface, and were able to induce more effective bone healing than steel drills, suggesting that Zr is a material that presents more favorable conditions for establishing osseointegration.

In relation to the design, an ideal geometric design to minimize heat induction has not yet been found (Mishra & Chowdhary, 2014; Möhlhenrich et al., 2015). Triple-twist cylindrical drills are most commonly used for preparing the implant site, as they have cutting efficiency and skillful elimination of bone fragments, which reduces resistance to friction (Cordioli et al., 1997). All studies included in this systematic review used drills with this type of design. Oh et al., 2011 modified the triple twist cylindrical drills, reducing the diameter and lateral cutting surface, which resulted in a significant reduction in heat induction. In addition, they suggested that reducing the area of the edges will increase the rifling channels that work as a way to remove bone fragments, which will result in less frictional heat induction. In this systematic review, the study by Hochscheidt et al., 2017 used a drill design with a 12° helix angle, while the other studies used 20° and/or 25° angles. This difference may be one of the possible explanations for the study showing an unfavorable performance for Zr, as smaller helix angles generally have larger edge surfaces, thus presenting greater friction (Harder et al., 2018).

Heat induction can also be influenced by the rotation speed of the drill and the pressure exerted. Sharawy et al., 2002 reported lower temperatures at higher drilling speeds (2500 rpm), as the increase in speed decreases the preparation time and requires less load application, which consequently reduces heat dissipation. Inadequate pressure during implant site preparation can cause higher bone temperatures and influence the health of the *peri*-implant bone (Ercoli et al., 2004; Sumer et al., 2011). In a systematic review by Mishra and Chowdhary, 2014 drilling speeds of 2,500 rpm with a load of 2–2,4 kPa were suggested as measures to reduce heat generation. In this current systematic review, only the study by Er et al., 2018 approached these measurements, using a load of 2 kPa and a speed of 2000 rpm; however, the results were not favorable for Zr drills, especially after 50 cycles of use (49.3 °C).

Other factors to be considered are the bone implant site preparation cycles and drill sterilization cycles. Scarano et al., 2007 evaluated the effect of reusing implant drills on thermal changes during implant site preparation and concluded that reuse causes an increase in bone heating. However, studies affirm that repeated use of a drill does not increase bone temperature above a critical level (Oliveira et al., 2012). Harris and Kohles et al., 2001 affirmed that repeated autoclave sterilization cycles reduced the cutting power of the drills. In this systematic review, all studies performed some method of hygiene, washing, and/or sterilization with each bone implant site preparation cycle.

Irrigation is an important factor in the prevention of high temperatures at the bone interface (Ercoli et al., 2004). Sener et al., 2009 investigated the heat generated between the external and internal irrigation systems during bone preparation for dental implants and found no significant difference between the systems. The clinical benefit of using a more expensive internal irrigation system is considerably unjustifiable (Mishra & Chowdhary, 2014).

The spongy bone has a reticulated structure that facilitates perforation and has a greater blood supply than the cortical bone, which helps in faster heat dissipation and has greater regeneration capacity (Albrektsson et al., 1981). Bovine and porcine bone models are considered very spongy bones, being described with a quality of D3-D4, which simulates only the region of the posterior maxilla (Mishra & Chowdhary, 2014). Therefore, the use of these specimens limits the clinical representation. Strbac et al., 1981 analyzed thermal induction in artificially manufactured bones, based on polyurethane, but these studies also have limitations as they represent only the cortical bone.

In a systematic review by Mishra & Chowdhary, 2014 several factors that influence heat generation during implant site preparation were evaluated, such as bone type, external versus internal irrigation, drill design, rotation speed, and pressure exerted. The study was inconclusive in defining the variable most responsible for bone heating during drilling. In contrast, this current systematic review and meta-analysis focused on the type of material of the drill as the main factor, which evidenced a less significant heat induction with Zr drills when compared to steel drills, so the type of material can also be seen as one of the factors that influence heat generation during implant site preparation.

This study has some limitations, such as limited number of studies included due to lack of scientific evidence, the inclusion of only in vitro studies, which limits the evaluation of biological properties and the difference in the methodological variables of the included studies, which may have influenced the results of the meta-analysis, despite this, the heterogeneity result was 0%. This heterogeneity is confirmed by the risk of bias result of the JBI, which is a risk of bias that has been adapted to judge in vitro studies, as the tool is easy to use. The meta-analysis was possible due to the comparison regarding the type of material used, other influencing factors being discarded, which are not determinant for the result of the meta-analysis, since low heterogeneity was found. Thus, new studies are recommended for a better understanding of the influence of the type of material on heat generation, mainly, the creation of in vivo studies because they would be better clinical representatives, especially for bone healing.

5. Conclusion

Despite the limitations of this review, it was concluded that Zr drills had significantly less temperature variation than SS drills.

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