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Systematic Review and Meta-Analysis
Dental Implants

Does the instrument used for the implant site preparation influence the bone–implant interface? A systematic review of clinical and animal studies

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Abstract. This systematic review evaluates the influence of the instrument used for the implant site preparation on the bone–implant interface. Any type of clinical or animal study were searched for in MEDLINE/PubMed, ISI Web of Science, and SciVerse Scopus. Two independent reviewers screened titles/abstracts of articles and the full-text of potentially eligible studies. Comparisons of bone to implant contact and crestal bone loss were estimated using pairwise meta-analysis. Twenty-nine studies met the inclusion criteria. The instruments identified in the articles were conventional drills (CDs), osteotome (OT), piezoelectric device (PD), Er:YAG LASER (LS) and osseodensification drills (ODs). The meta-analysis on bone to implant contact suggested no difference between CDs and other techniques and the meta-analysis on crestal bone loss suggested no difference between CDs and PD. The survival of implants in sites prepared with CDs vs. OT or PD presented no significant differences. The use of PD provided lower inflammatory response and earlier bone formation when compared to CDs. ODs provided significant biomechanical improvement in comparison to CDs. LS did not provide any relevant improvement in comparison to CDs or PD. The influence of the instrument used for implant site preparation depended on the property evaluated.

Key words: implant site preparation; implant survival; biomechanics; histological analysis.

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Since the beginning of dental implant therapy, the technique used for the implant site preparation has been considered one of the most important factors affecting osseointegration[1]. The maintenance of the bone volume and bone histologic structure has been considered dependent on the procedures performed during the bone preparation[2]. Therefore, instruments for implant site preparation capable of improving osseointegration are desirable.

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The conventional progressive drilling technique is the classical method for implant site preparation, using successively increasing-diameter clockwise twisted drills rotating from 800 to 1500 rpm under abundant irrigation in order to avoid overheating of the bone[3]. It is clear that both researchers and manufacturers worked to develop instruments to improve osseointegration and overcome some technique sensitivities of the conventional drilling procedure such as risk of bone necrosis, risk of damage to adjacent structures, and drilling precision.

The osteotome (OT) was introduced to improve bone–implant interface properties increasing the initial stability of implants placed in low-density bones, especially in the posterior maxilla[4]. It consists of a sequence of bone condenser instruments used in crescent diameters, which compress the trabecular bone apically and laterally simultaneous to bone expansion.

The piezoelectric device (PD) was introduced to implant dentistry aiming to provide bone preparation by means of multi-frequency ultrasonic vibrations[5]. A sequence of inserts with crescent diameter is used under saline irrigation for bone preparation. Some of the main advantages related to the use of this instrument are the cut precision, avoidance of bone overheating, avoidance of damage to neighbouring soft tissues, and easy bone removal.

The use of Er:YAG LASER (LS) presented as an alternative for implant site preparation. Its 2940-nm wavelength permits high affinity with hydroxyapatite and water, with the ability to ablate bone tissue. LS performs the implant site preparation by pulsing emission, without contact or attrition, under saline irrigation. Used correctly, it does not cause residual thermal effects or necrosis of bone cells, which could directly favour the tissue reparation and accelerate osseointegration. The difficulty related to the use of LS consists of its irregular ablation pattern, which is inversely proportional to the surgeon's ability to control the extension of bone preparation[6].

Some of the most recent instruments introduced are drills designed to be used in the clockwise or counter-clockwise direction to increase the bone density, a technique currently known as osseodensification. The drills are used at speeds ranging from 800 to 1200 rpm in bouncing movements under profuse irrigation. They consist of a non-subtractive method where the drills increase the bone density while expanding the implant site[2].

Some clinical and animal studies evaluated the impact of these different instruments on the bone–implant interface. None of the consulted papers compared the outcomes of all instruments available. The aim of this systematic review was to evaluate the influence of different instruments used for implant site preparation on the bone–implant interface.

Materials and methods

The present systematic review followed the four-phase flow set forth in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement[7] and it was reported based on the same guidelines.

Criteria for selecting studies

We included randomized or non-randomized controlled clinical studies or experimental studies in animal models, published in English, and comparing at least two different instruments for dental implant site preparation, and evaluating bone response through any type of clinical, biomechanical or histological evaluation. We excluded the following types of article: studies in ex vivo bone tissue and case reports.

Electronic searches

Searches were performed in three online databases (MEDLINE/PubMed, ISI Web of Science, and SciVerse Scopus) and the last search was performed in October 2017. The literature search strategy for each database is available in Table 1. In addition, a manual search was conducted in the following Journals: *British Journal of Oral and Maxillofacial Surgery, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implantology, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery, International Journal of Periodontics and Restorative Dentistry, Journal of Clinical Periodontology, Journal of Oral Implantology, Journal of Craniofacial Surgery, Journal of Cranio-Maxillofacial Surgery, Journal of Maxillofacial and Oral Surgery, Journal of Oral and Maxillofacial Surgery, Journal of Periodontology, Periodontology 2000*.

Screening and selection

Two independent reviewers screened all titles/abstracts of articles and the full text of potentially eligible studies was retrieved and reviewed for eligibility. Articles that fulfilled the eligibility criteria were included in the study. The reviewers handsearched the reference lists of included articles for additional papers. Any disagreement between the two reviewers was resolved after additional discussion. Papers that fulfilled the selection criteria were processed for data extraction.

Data extraction

A standardized data extraction form was used to collect the following data: author/year, population, number of implants, comparison tested, type of analysis and results. The data extraction form was created through consensus meeting between the two reviewers, but only one reviewer extracted all items. In the event of doubt, the opinions of the other reviewers were garnered.

Data analysis

A descriptive presentation of the results was used to summarize the findings considering the type of included studies (clinical or animal). When sufficient data were available, comparisons among techniques were estimated using pairwise meta-analysis to calculated pooled mean differences. Considering animal studies, we used the bone to implant contact (BIC) as the outcome independently of animal model, and for clinical studies, we used crestal bone loss. When the article reported more than one duration of follow-up, we considered only the longer period in the analysis. All summary estimates were reported with point estimates and corresponding 95% confidence intervals (CIs). Statistical heterogeneity was evaluated using the Cochrane Q statistic and I^2 (>75% indicates high heterogeneity). All analyses were performed using the random effects model and conducted in Review Manager 5.3 software (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014).

Results

Study selection

Manuscript selection is presented in Fig. 1. The initial search resulted in 1027 articles. First, 68 duplicate articles were removed. After that, a screening of titles and abstracts was performed, where 45 complete articles

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Table 1. Detailed search terms used in each database.

Database	Search terms
PubMed	(dental implant stability* OR primary implant stability* OR osseointegration* OR implant bone response* OR implant bone formation*) AND (implant osteotomy* OR implant drilling technique* OR implant socket preparation* OR implant site preparation* OR implant surgical technique*)
ISI Web of Science and SciVerse Scopus	(dental implant stability* OR primary implant stability* OR osseointegration* OR implant bone response* OR implant bone formation*[title]) AND (implant osteotomy* OR implant drilling technique* OR implant socket preparation* OR implant site preparation* OR implant surgical technique*[title])

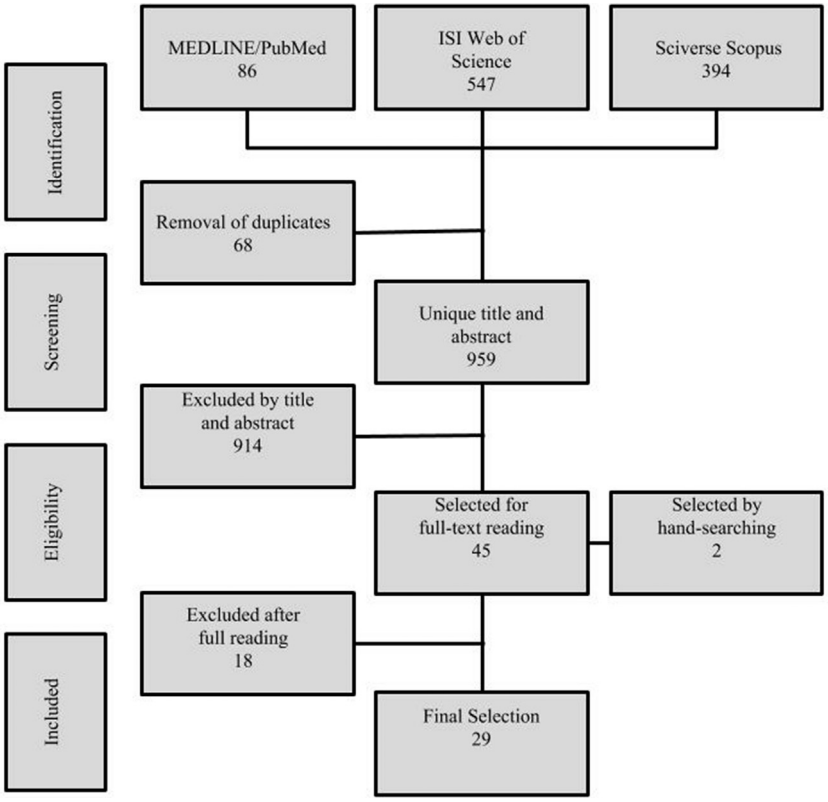

Fig. 1. Flow diagram of the systematic review.

remained. In total, 18 articles were excluded after full-text reading for the following reasons: 11 studies presented procedures that were not considered as different instruments for bone preparation, but only a change in the conventional technique; and seven studies did not present clinical or animal evaluation. Two articles were selected by manual search in international journals and bibliographic references of articles selected for complete reading. In total, 29 articles were identified as eligible and included in the systematic review.

Characteristics of study

Tables 2 and 3 feature the characteristics of each included study considering the type of research design (animal or clinical). Fifteen studies were experimental studies in animal models and 14 studies were classified as clinical studies. The animals most used in the studies were sheep ($n = 4$) and dogs ($n = 4$). The design of clinical studies included were non-randomized controlled trials (N-RCTs; $n = 2$), randomized controlled trials (RCTs; $n = 11$), and controlled but randomization not clear (unclear; $n = 1$). The oldest publication dates were from 2002 and the most recent one was from 2017.

The instruments identified in the articles were conventional drills (CDs), OT, PD, LS, and osseodensification drills (ODs). Of the twenty-nine studies that were included in this review, 13 studies compared the CDs vs. OT, 12 studies CDs vs. PD, one study CDs vs. LS, two studies CDs vs. ODs, and one study CDs vs. PD vs. LS.

CDs vs. OT

Five animal studies and eight clinical studies compared the use of CDs to the use of OT in low-density bones. The crestal bone loss was evaluated by two studies. One evaluation showed lower bone loss in the CD group after 180 days[21]. A second study showed also greater bone loss in the OT group after 90 days, but similar results after 6 and 12 months[23]. According to the information present in the studies, implant survival did not differ between groups at the end of the evaluations[21–26].

Biomechanical analysis was performed in seven clinical and three animal studies. Results for implant stability quotient (ISQ) (eight studies) based on one animal study and four clinical studies (62.5% of the data) revealed similar values between the methods[9,25–28]. One clinical study revealed higher ISQ for the CD group on the day of implantation, but no difference after 180 days[21]. Two studies (25%) presented an advantage for the OT: one presented higher ISQ for the OT group after implantation but not after 3 months[23], and the other presented higher ISQ for the OT group immediately after surgery and for a whole observation period of 6 weeks[22]. The insertion torque (IT) was evaluated by one study without difference between groups[25]. Removal torque test (RT) revealed higher stability for implants installed in sites prepared with CDs[9].

Histological evaluation was performed in three animal studies. In histological analyses, the bone to implant contact (BIC) did not present initial differences (at 7 days) in one study, but better BIC for the CD group after 28 days[10]. Two studies revealed better initial BIC in the OT group in the first 0–3 weeks[11] and 2–4 weeks[8], but no significant difference after 8 weeks. Bone area ratio (BAR) was evaluated by one study and showed similar results between groups[8].

The bone temperature before and during implant placement was evaluated in one clinical study, which demonstrated significant higher bone temperatures in the OT group[24]. However, all temperatures were considered below threshold for thermal necrosis.

Three studies evaluated the bone density around implants. All evaluations observed statistically significant higher values for the OT group[8,9,12]. One study

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Table 2. Data from animal studies.

Year and study	Population	Number of implants (*n*)	Instruments compared	Analysis	Results
2002 Nkenke et al.[8]	Rabbits	NT = 104 NG = 52	CDs vs. OT	BIC and BAR by histomorphometric analysis Fluorescence microscopic analysis	BIC was significantly higher for OT group at 2 and 4 weeks At 8 weeks, no difference was observed between groups The BAR did not differ among groups during the study New bone formation began earlier with OT than after CDs Highly dense bone was observed around implant in OT group in all periods
2005 Büchter et al.[9]	Minipigs	NT = 56 NG = 28	CDs vs. OT	RT test ISQ by RFA Histological analysis	Higher RT of implants in the CD group at days 7 and 28 ISQ did not differ between groups Histological analysis demonstrated fractured trabeculae in peri-implant bone in the OT group at day 7, while they were not posed at day 28
2005 Büchter et al.[10]	Minipig	NT = 64 NG = 32	CDs vs. OT	BIC by histomorphometric analysis Fluorescence microscopy SEM	BIC was similar for both techniques at 7 days After 28 days, BIC was statistically significant higher when CDs were used A higher density of peri-implant bone was observed in the OT group No relevant differences observed between structures of the two groups by SEM
2006 Kim et al.[11]	Dogs	NT = 72 NG = 36	CDs vs. OT	BIC by histomorphometric analysis ISQ by RFA	At weeks 0 and 3, the OT group showed higher BIC and ISQ At 8 weeks, there was no significant difference in BIC and ISQ between groups
2017 Wang et al.[12]	Mouse	NT = 58 NG = 58	CDs vs. OT	Finite element analysis Histology and immunohistochemistry Microcomputed tomography Lateral stability quotient (ISQ)	OT created high interfacial strains that caused fractures and triggered a prolonged period of bone resorption OT increased the density of peri-implant bone; however, it did not improve ISQ, which was credited to the funnel-shaped bony deficits caused
2007 Preti et al.[5]	Minipig	NT = 16 NG = 8	CDs vs. PD	Histomorphology and levels of bone morphogenetic protein-4, transforming growth factor-b2, tumor necrosis factor-alpha, and interleukin-1b and -10	Bone around the implants treated with the PD showed an earlier increase in bone morphogenetic protein-4 and transforming growth factor-b2 proteins as well as a reduction in pro-inflammatory cytokines More inflammatory cells were present in samples from CD sites Neo-osteogenesis was consistently more active in bone samples from the implant sites that were prepared using PD
2014 Bengazi et al.[13]	Dog	NT = 30 NC = 18 NP = 12	CDs vs. PD	Final IT ISQ by RFA Histological analysis for BIC	There was no significant difference for IT, ISQ and BIC between the groups
2014 Kfouri et al.[14]	Rabbit	NT = 96 NG = 58	CDs vs. PD	Histomorphometric analysis for BV, BIC, media thickness, separation and number of trabeculae around the loops	PD provided results similar to those of the CDs

2015 Viganò et al.[15]	Dogs	NT = 24 NG = 12	CDs vs. PD	Histological and histometric evaluations for BIC, hard and soft tissue dimensions	No significant differences were found for BIC and any of the histological variables evaluated for hard and soft tissue dimensions
2015 Zizzari et al.[16]	Sheep	NT = 24 NG = 12	CDs vs. PD	Histological analysis Immunohistochemical evaluation of iNOS and Bax expression	Histological analysis revealed more rapid healing around implants positioned using PD and the presence of a more organized newly formed bone tissue compared to those inserted with CDs No significant iNOS and Bax expression was recorded between groups
2016 Sirolli et al.[17]	Mouse	NT = 30 NG = 15	CDs vs. PD	Histometric analysis – PMT adjacent to implant threads, bone area within the threads, and BIC	A higher percentage of bone area within the threads was observed in the PD group in the cortical and cancellous bone The PD showed higher PMT values in the cancellous zone CD group presented better results for BIC in cortical region There were no significant differences between both groups for cancellous BIC and cortical PMT
2010 Stübinger et al.[18]	Sheep	NT = 108 NG = 36	CDs vs. PD vs. LS	Histological evaluation of BIC Biomechanical RT	Statistical analysis of the average mean BIC after 4, 6 and 8 weeks revealed no significant differences among instruments Comparison of individual RT values showed the highest value for LS osteotomy after 8 weeks, which was significantly higher than the corresponding value for CDs
2007 Schwarz et al.[6]	Dogs	NT = 24 NG = 12	CDs vs. LS	Histomorphometrical analysis of width of the peri-implant gap (WPG) and BIC	LS osteotomy resulted in wide peri-implant gaps particularly in the apical area of the implant supporting bone After 2 weeks, BIC of the LS group was significantly lower than CDs Differences in BIC were not observed after 12 weeks
2016 Trisi et al.[19]	Sheep	NT = 20 NG = 10	CDs vs. ODs	Value of actual micromotion RT Histological analysis: BIC and % of bone volume (%BV)	The ODs led to increased primary stability and similar secondary stability compared with CDs In general, ODs presented higher value of actual micromotion, RT, BIC, and %BV
2016 Lahens et al.[20]	Sheep	NT = 30 NG = 10	CDs vs. clockwise osseodensification × counter-clockwise osseodensification	IT Histological evaluation of BIC, bone-area-fraction occupancy	Implants presented higher IT levels when placed in OD sites There was no statistical difference in bone-area-fraction occupancy as a function of instrument A significantly higher BIC for both OD techniques was observed compared to CDs

References were ordered by year according to the instruments compared. BAR, bone area ratio; BIC, bone to implant contact; BV, bone volume; CD, conventional drill; ISQ, implant stability quotient; IT, insertion torque; LS, Er:YAG LASER; NG, number of implants per group; NT, total number of implants in the study; OD, osseodensification drill; OT, osteotome; PD, piezoelectric device; PMT, proportion of mineralized tissue; RFA, resonance frequency analysis; RT, removal torque test; SEM, scanning electron microscopy.

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Table 3. Data obtained in clinical studies.

Year and study	Design	Number of implants (*n*)	Instruments compared	Analysis	Results
2010 Padmanabhaand Gupta[21]	N-RCT	NT = 10 NG = 5	CDs vs. OT	ISQ by RFA Peri-implant bone loss measured radiographically	Significantly higher ISQ in CD group on the day of surgery However, no statistically significant difference in ISQ was found between instruments on 180th day Significantly lower crestal bone loss after 180 days with CDs All implants survived after the 6-month follow-up
2011 Markovic et al.[22]	N-RCT	NT = 48 NG = 24	CDs vs. OT	ISQ by RFA	Significantly higher ISQ for the OT group either immediately after surgery or during the whole observation period of 6 weeks compared with CDs All implants survived after 6-week follow-up
2013 Shayesteh et al.[23]	RCT	NT = 46 NG = 23	CDs vs. OT	Crestal bone loss ISQ by RFA	RFA revealed higher ISQ for implants in the OT group at the time of implant insertion However, there was no significant difference between both groups 3 months after the surgery At month 3, the OT group had significantly more crestal bone loss than the CD group At months 6 and 12, both groups had comparable bone levels All implants survived after 1 year
2014 Markovic et al.[24]	RCT	NT = 40 NG = 20	CDs vs. OT	Bone temperature recorded prior to implantation and during implantation by an infrared thermographic camera Early implant success was evaluated after 6 months of healing	All recorded bone temperatures were below the threshold for thermal necrosis Although both groups showed significant increase in bone temperature during implant placement procedure, it was significantly higher for OT compared with CDs Early implant success rate after 6 months' follow-up was 100%
2015 Xing et al.[25]	RCT	NT = 16 NG = 8	CDs vs. OT	IT Primary and secondary stability (ISQ) by RFA	No significant difference between IT and ISQ between the two groups was found across the study Survival rate at the end of 90 days was not clearly described
2015 Sadeghi et al.[26]	RCT	NT = 54 NG = 25/29	CDs vs. OT	ISQ by RFA	There was no significant difference between the two groups in ISQ at any of the measurement times There was 100% of survival after 3 months' follow-up
2017 Hong et al.[27]	N-RCT	NT = 24 NG = 12	CDs vs. OT	ISQ by RFA	OT achieved comparable ISQ with the CDs There was no clear information about implant survival after the 3 months of study
2017 Lin et al.[28]	RCT	NT = 58 NG = 26/32	CDs vs. OT	ISQ by RFA	The OT group achieved a comparable ISQ than did the CDs No clear information about implant survival after the 3 months of study
2010 Di Alberti et al.[29]	RCT	NT = 80 NG = 40	CDs vs. PD	Bone density by densitometry	PD promoted better bone density All implants survived after 3-month follow-up
2013 Stacchi et al.[30]	RCT	NT = 40 NG = 20	CDs vs. PD	ISQ by RFA	Statistical significance of ISQ between groups was not observed One failure occurred in the CD group during osseointegration Survival of implants did not differ between groups after 1 year

2014 Da Silva Neto et al.[31]	RCT	NT = 68 NG = 34	CDs vs. PD	ISQ by RFA	The ISQ of PD group was greater than that of CDs for all periods evaluated – immediately, after 90, and 150 days All implants survived after 150 days
2014 Canullo et al.[32]	RCT	NT = 30 NG = 15	CDs vs. PD	ISQ by RFA Peri-implant marginal bone loss	ISQ was significantly higher in the PD group at the 8-week assessment; differences were non-significant at all other time-points (1, 3 and 12 weeks) No difference was found in peri-implant marginal bone loss between the groups One failure occurred in the control group during osseointegration Difference in the implant survival was not observed after 15 months
2016 Tekdal et al.[33]	RCT	NT = 38 NG = 19	CDs vs. PD	Crestal bone loss IT Probing depth Gingival and plaque indices RANKL and osteoprotegerin	Crestal bone loss values and IT did not depend on the instrument Osteoprotegerin, gingival and plaque indices, and probing depth did not differ between groups PD group had lower RANKL total amount than the CD group, suggesting decreased osteoclastic activity All implants survived after 24 weeks
2017 Makary et al.[34]	RCT	NT = 21 NG = 10/11	CDs vs. PD	IT ISQ by RFA removal torque	Comparable implant IT, ISQ, and removal torque between groups All implants survived after 4 weeks

References were ordered by year according to the instruments compared. CD, conventional drill; ISQ, implant stability quotient; IT, insertion torque; LS, Er:YAG LASER; NG, number of implants per group; NT, total number of implants in the study; OD, osseodensification drill; OT, osteotome; PD, piezoelectric device; RANKL, receptor activator of nuclear factor kappa-B-ligand; RFA, resonance frequency analysis. Studies encompassed non-randomized controlled clinical trials (N-RCT) and randomized controlled clinical trials (RCT).

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observed that new bone formation begins earlier with OT than with CDs[8]. However, in another evaluation, OT caused high interfacial strains that caused fractures and triggered a prolonged period of bone resorption[12]. Another histological analysis demonstrated also fractured trabeculae in peri-implant bone in the OT group at day 7, while they were not observed by day 28[9].

CDs vs. PD

Twelve studies were selected, including six clinical studies and six animal studies. Crestal bone loss was evaluated by two clinical studies and was shown not to be dependent on the instrument[32,33]. Probing depth, gingival and plaque indexes were evaluated in a single clinical study and did not differ between groups[33]. Data from the clinical studies revealed similar implant survival at the end of the evaluations[29–34].

Biomechanical analysis was assessed by four clinical studies and one animal study. ISQ did not present differences between groups in 60% of the analysis (two clinical and one animal study)[13,30,34]. One clinical study (20%) revealed higher ISQ for the PD group[31]. The other clinical analysis (20%) revealed higher ISQ for PD only at one period (after 8 weeks) of the four periods evaluated (1, 3, 8 and 12 weeks)[32]. The IT was measured by two clinical studies and one animal study and did not present differences between groups[13,33,34]. The RT evaluated by one clinical study showed similarity between groups[34].

Histological analysis of the BIC was performed by four studies in animals. Three studies (75%) presented no differences between groups[13–15]. One revealed better results for CDs in cortical bone, but similar results in cancellous bone[17].

Histometric analysis revealed higher values of bone area within threads (BA) and higher proportion of mineralized tissue (PMT) values in the cancellous zone in sites prepared with PD in one animal study[17]. A single clinical study revealed better bone density after PD preparation[29]. Another animal study showed no differences in bone volume in sites prepared with CDs or PD[14,15].

In one of the animal studies, there was a more rapid healing around implants positioned after using PD and the presence of a more organized newly formed bone tissue compared to sites prepared with CDs[16]. In one clinical study, the PD group had lower receptor activator of nuclear factor kappa-B-ligand (RANKL) total amount than the CD group, suggesting decreased osteoclastic activity[33].

One animal study revealed that bone around the implant prepared with PD showed an earlier increase in BMP-4 and TGF-b2 proteins (proteins involved in bone development), as well as a reduction in proinflammatory cytokines[5]. Moreover, a higher number of inflammatory cells were present in samples from CD sites[5]. Neo-osteogenesis was consistently more active in bone samples from the implant sites than those prepared using PD[5].

CDs vs. LS

One animal study was selected[6]. Histologic evaluation revealed lower BIC for the LS group after 2 weeks, without differences between the two groups after 12 weeks. LS osteotomy also resulted in wider gaps at peri-implant interface.

CDs vs. PD vs. LS

One animal study was included in the review[18]. In the analysis, biomechanical evaluation revealed significantly higher RT for the LS group after 8 weeks in comparison with the CD group. Histological analysis showed no difference in BIC among groups.

CDs vs. ODs

Two animal studies were observed[19,20]. All biomechanical evaluations presented significant benefits with the OD group, including higher IT, higher RT, and increased primary and secondary stability (ISQ). Histological analysis revealed significantly higher BIC in the OD group in both studies. A significantly higher bone volume around implants was also observed for the OD group in one of the studies[19].

Meta-analysis

Figure 2 presents the comparisons between techniques considering BIC as outcome. Figure 2A shows the results of the meta-analysis for CDs and OT. The pooled effect indicated no significant differences (4.37; 95% CI −9.09 to 17.84) and the $I^2 = 98\%$. Figure 2B shows the results of the meta-analysis for CDs and PD. The pooled effect indicated no significant differences (−0.57; 95% CI −3.97 to 2.84) and the $I^2 = 0\%$. Figure 2C shows the results of the meta-analysis for CDs and LS. The pooled effect indicated no significant differences (−0.56; 95% CI −10.65 and 9.52) and the $I^2 = 72\%$. Figure 2D shows the results of the meta-analysis for CDs and ODs. The pooled effect indicated no significant differences (−9.48; 95% CI −22.73 to 3.77) and the $I^2 = 87\%$.

Figure 3 presents the comparison between CDs and PD considering crestal bone loss as the outcome. The pooled effect indicated no significant differences (0.02; 95% CI −0.09, 0.13) and the $I^2 = 0\%$.

Discussion

This review is the first to try to confirm whether the instrument used for implant site preparation influences the bone–implant interface. Our findings demonstrated different results among the methods and outcomes evaluated. Regarding the clinical longevity of the implants, all studies presenting outcomes for the comparison of CDs vs. OT[21–26,28] and CDs vs. PD[29–34] showed no differences in the implant survival. Studies comparing survival of groups CD vs. OT evaluated 143 and 153 implants, respectively, and no implant was lost. The clinical comparison of CDs vs. PD involved 138 and 139 implants placed, respectively. In these studies, only two implants were lost, when CDs were used.[30,32] These results might be explained by the fact that the implants of the randomized clinical trials were placed by experienced professionals in healthy subjects, factors that have been considered as significantly important to the implant survival[35,36]. Moreover, similarity might have occurred because both instruments used correctly provide adequate primary stability and do not generate bone heating above the necrosis threshold. It is worth mentioning that more time of follow-up is needed considering that the time of evaluation ranged from 1 month to 2 years.

In the selected studies, the crestal bone loss was lower in peri-implant region when the implant site was prepared with CDs in comparison to OT[21,23]. These findings might be explained by the complementary histologic evaluations observed in other reviewed papers. Implant sites prepared with OT showed a higher number of fractures[12] and a prolonged period of bone resorption[12]. Regarding the comparison between CDs and PD, no significant difference in crestal loss, probing depth, gingival and plaque indices were observed[33]. Besides the lower inflammatory response and the earlier new bone formation when sites were prepared with PD[5,16], it seems not to improve these clinical parameters.

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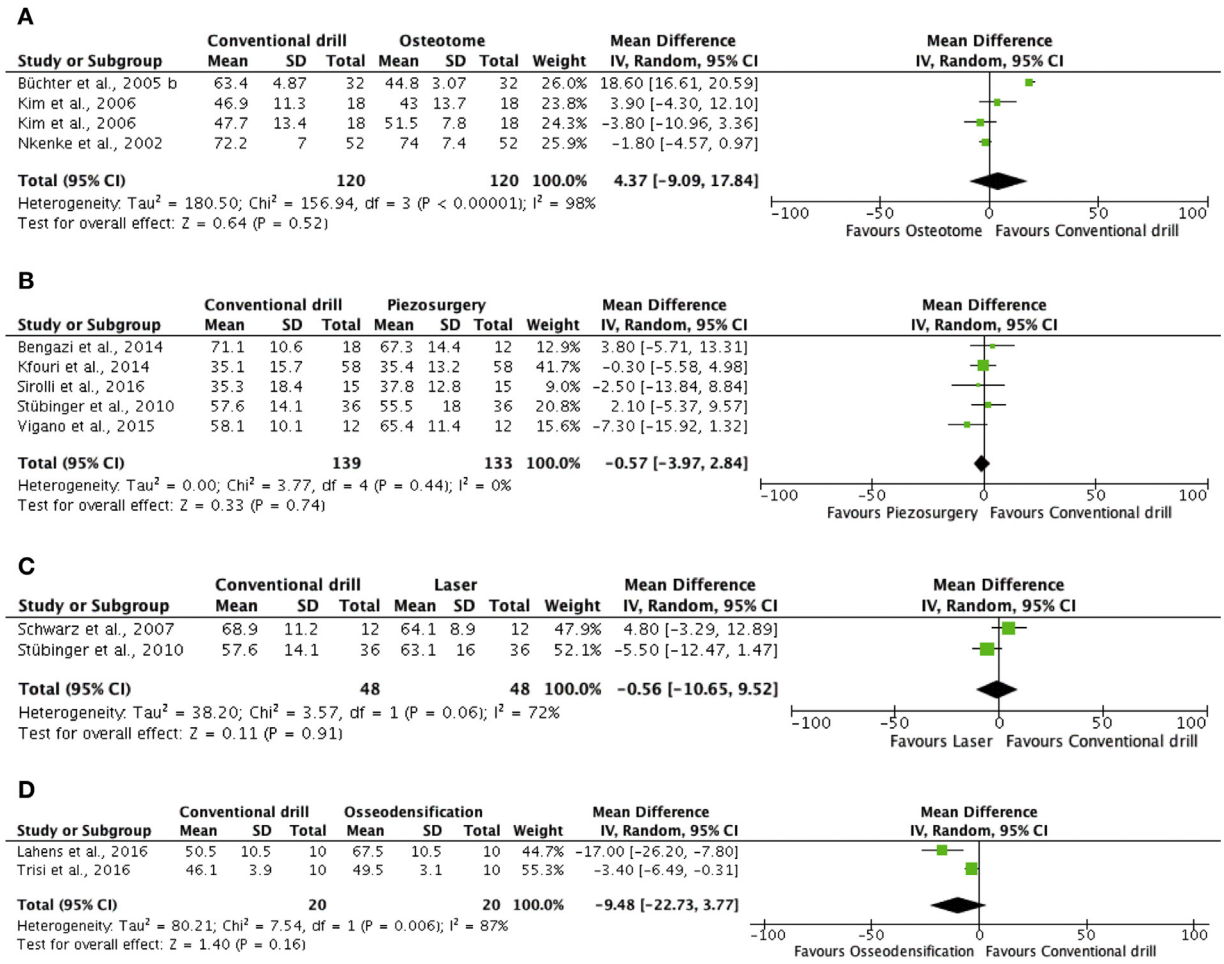

Fig. 2. Meta-analysis for the bone-to-implant contact results in animal studies. (A) Conventional drill vs. osteotome; (B) conventional drill vs. piezoeletic device; (C) conventional drill vs. LASER; (D) conventional drill vs. osseodensification drill.

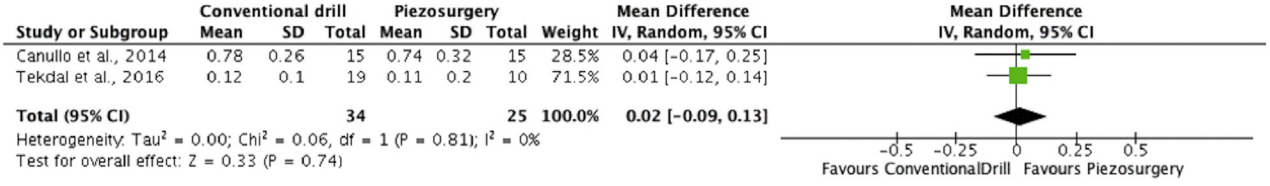

Fig. 3. Meta-analysis evaluating bone loss for the techniques conventional drills vs. piezoelectric device.

Biomechanical analysis revealed that, in general, no significant differences between site preparation with CD × OT occurs at the implant–bone interface with regard to ISQ, RT and IT[9,12,25–28]. OT presents some advantages such as increased bone density around implants[8,10,12], which could improve biomechanical properties. However, the presence of micro-fractures observed in the histologic evaluation[9,12] might be indicated as one of the reasons for jeopardizing the advantages mentioned above. PD led to increased initial bone density in one study[29]; however, this only reflected positively in the test of RT[34]. ISQ and IT seem to be more related to other factors reported in other studies of literature such as bone density and professional ability.

Only one biomechanical evidence was observed for the comparison of LS with CDs and PD[18]. LS presented greater RT than CDs after 8 weeks. This was credited to the residual thermal effects caused by the LS, which improves tissue reparation and accelerates osseointegration. However, no overall benefit of LS was observed as RT was similar between groups at follow-up periods of 1, 3 and 12 months. The major biomechanical improvement to the conventional drilling was observed when ODs were used. Significantly higher IT, RT, and ISQ were measured in OD groups[19,20]. This has been attributed to the significant increase in bone density caused[19].

The histological analysis showed overall similar results of BIC of CDs compared with OT[8,10,11], PD[14,15], LS[6,18], or ODs[19,20]. BAR was also not significant between CDs and OT[8] in the selected studies. Therefore, there are some advantages to using more recent instruments such as the higher bone density (caused by OT and PD)[8,10,12,29], the lower inflammatory response (caused by PD)[5,33], and

the lower bone heating (caused by LS)[6]; however, they provide similar BIC when CDs are used in the correct way. A higher percentage bone volume around implants was seen with ODs[21]. The much higher bone density around implants supports these findings[19,20].

Despite the similarity in BIC between CDs and PD, one clinical study revealed better bone density after preparation with PD[29]. Higher values of bone area within threads (BA)[18] and higher PMT values[5,17] in the cancellous zone were observed in sites prepared with PD in two different animal studies. These findings might be explained by the several advantages of the use of PD with regard to tissue response. The main advantages observed were more rapid healing around implants, more organized newly formed bone tissue, decreased osteoclastic activity, earlier increase in proteins involved in bone development (BMP-4 and TGF-b2), reduction in pro-inflammatory cytokines, and lower number of inflammatory cells[5,16,33].

The clinical comparison between the preparation with CDs vs. OT or PD was performed only in short-term follow-up periods up to 2 years. Therefore, longer studies with greater populations would be desirable. Moreover, the use of ODs showed promising results but were evaluated only in animal studies in short periods. The use of ODs showed encouraging results to be applied in clinical researches.

From the general observation of this systematic review, OT did not improve the bone–implant interface in comparison with CDs, but it is worth mentioning that OT has other uses, such as to perform bone expansion. A relevant number of studies evaluated PD and it seemed to provide better biologic response when compared to CDs. Few evidences were observed about the use of LS and ODs. LS was shown not to provide relevant benefits. ODs showed promising and encouraging results because of the significant increase in the biomechanical properties.

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Competing interests

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Ethical approval

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Patient consent

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