

Treating periodontitis-A systematic review and meta-analysis comparing ultrasonic and manual subgingival scaling at different probing pocket depths.

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Research article

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Abstract

Background: Mechanical plaque removal has been commonly accepted to be the basis for periodontal treatment. This study aims to compare the effectiveness of ultrasonic and manual subgingival scaling at different initial probing pocket depths (PPD) in periodontal treatment.

Methods: Public databases were searched. Weighted mean differences in PPD and clinical attachment loss (CAL) reduction were estimated by random effects model. Bleeding on probing (BOP), gingival recession (GR), and post-scaling residual dental calculus were analyzed by comparing the results of each study.

Results: Ten randomized controlled trials were included out of 1,434 identified. Selected outcomes were PPD and CAL. Initial PPD and follow-up periods formed subgroups. For 3-month follow-up: (1) too few shallow initial pocket studies available to draw a conclusion; (2) the heterogeneity of medium depth studies was so high that could not be merged to draw a conclusion; (3) deep pocket studies showed no statistical differences in PPD and CAL reduction between ultrasonic and manual groups. For 6-month follow-up: (1) too few shallow initial PPD studies to draw a conclusion; (2) at medium pocket depth, PPD reduction showed manual subgingival scaling better than ultrasound. No statistical differences were observed in CAL reduction between the two approaches; (3) for deep initial PPD studies, both PPD and CAL reduction showed manual subgingival scaling better. GR results indicated no statistical differences at medium and deep initial pocket studies between the two methods. BOP results showed more reduction at deep pocket depths with manual subgingival scaling. No conclusion could be drawn about residual dental calculus.

Conclusion: When initial probing pocket depth was 4-6mm, PPD reduction proved manual scaling superior to ultrasonic subgingival scaling, but CAL and GR results showed no statistical differences between the two means. When initial probing pocket depth was ≥ 6 mm, PPD, CAL and BOP reductions suggested that manual subgingival scaling was superior to ultrasonic subgingival scaling, but GR results showed no statistical differences. No conclusion could be drawn about residual dental calculus.

Background

Periodontitis is characterized by gingivitis and periodontal tissue destruction resulting in alveolar bone and tooth loss [1]. The 2010 Global Burden of Diseases Study reports that periodontitis is the sixth most common disease with a standardized prevalence of 11.2%. It is the primary cause of tooth loss [2]. It negatively affects oral health, nutrition, self-confidence, and overall health. It associates with various systemic chronic inflammatory diseases such as angiocardopathy and diabetes. Periodontitis is a primary public health problem [3].

Dental plaque biofilm is the initial factor of periodontitis, which aggregates to trigger immune responses. This tends to destroy surrounded soft tissues and alveolar bone. [3]The goal of periodontal treatment is to control infection, and remove dental plaque, dental calculus, and endotoxins [4]. It was confirmed that subgingival scaling was an effective non-surgical periodontal therapy. In the early stage, subgingival scaling was practiced with manual scaling. In recent years, ultrasonic subgingival scaling has been applied in periodontal clinic [1, 5–8]. Each technique has advantages and disadvantages. Currently there is no universal protocol or clinical guideline for selecting one technique over another.

Many in-vivo studies did not group by initial initial probing pocket depth (PPD) when comparing ultrasonic and manual subgingival scaling, but different PPD may greatly influence instrument selection. For example, Beuchat found that when initial PPD < 6 mm, for gingival recession (GR), there was no statistical significance between ultrasonic and manual subgingival scaling ($P < 0.05$). When initial PPD > 7 mm, attachment level (AL) improved more while GR reduced more in using ultrasonic instruments than using manual instruments [9]. It is controversial in terms of when to use manual subgingival instrument and when to use ultrasonic ones.

In this study, we aimed to compare the work effectiveness between ultrasonic and manual subgingival scaling in different initial PPDs. It can provide new evidences for clinical instrument selection and future study.

Abbreviations used herein appear in Table 3.

Methods

A protocol has been registered at the International Prospective Register of Systematic Reviews (Number CRD42019125067). The content of this article is consistent with the protocol.

Research question

The focused question was developed in accordance with recognized Patient, Intervention, Comparison, and Outcome (PICO) format: "What's the difference of the work effectiveness between ultrasonic and manual subgingival scaling in periodontal treatment at different initial PPDs?"

Selection Criteria

Study type:

Only manual- or ultrasonic- subgingival scaling treated patients with periodontitis in a completely randomized controlled trial (RCT) were included. Subjects were classified clinically by grouping initial PPDs into: (1) shallow pocket: $PPD \leq 4\text{mm}$; (2) medium pocket: $4\text{mm} < PPD < 6\text{mm}$; or, (3) deep pocket: $PPD \geq 6\text{mm}$. Studies had to be in-vivo and compare ultrasonic subgingival scaling with manual subgingival scaling for inclusion. A group could not be simultaneously included in different PPD categories. Single-rooted or multi-rooted teeth were not considered in the selection process. In other words, we did not include or exclude one paper whether it is single-rooted or not.

Participants:

Adults (age ≥ 18) diagnosed with periodontitis unaccompanied by any other oral or systemic disease and not taking antibiotics.

Intervention:

Meta-analysis sought to eliminate bias caused by different initial PPD to compare ultrasonic and manual subgingival scaling. No distinctions were made between ultrasonic subgingival instrument makers or models. A Gracey scraper was chosen as the manual instrument.

Outcomes:

A study may have primary and secondary indicators. Each indicator was processed differently. Not all outcomes were consistent with the criteria. The outcomes included appear in tables. (Table 1 and 2).

(1) Primary outcomes:

PPD and clinical attachment loss (CAL) were the primary outcomes to compare different subgroup outcomes.

(2) Secondary outcomes:

Bleeding on probing (BOP), gingival recession (GR), and post-scaling residual dental calculus were used as measures. These indicators are of interest, but data about them could not be extracted for meta-analysis due to the limited number of studies, their different measurements, and definitions. They were analyzed by comparing the results of each study.

Studies meeting the following conditions were excluded: (1) follow-up in less than 3 months; (2) treatment during follow-up. Cluster trials were not included.

Search strategy

PubMed, Cochrane Central Register of Controlled Trials, EMBASE, Medline, and [ClinicalTrials.gov](https://www.clinicaltrials.gov) were searched until January, 2019 for relevant studies. The search was performed using a combination of controlled vocabulary and key words (Table S1). Only English articles were searched. No time restrictions were imposed.

Potentially eligible studies were considered for review. A manual search using reference lists of related articles was performed.

Data Collection and Analyses

(1) Study selection and quality assessment.

Three review authors (Zhang, Hu, and Zhu) independently searched and included eligible studies, using the same search strategy which had been completed and improved. The quality of each study was reviewed and evaluated for 3 times by three authors and relevant data were extracted. When there was a disagreement whether to include or not, a discussion with other authors (Chen and Li) was held and an agreement reached on inclusion or exclusion.

A study's methodological quality was assessed using the original publication. Trial quality was evaluated using Cochrane review bias assessment risk criteria [10].

This included random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel blinding (performance bias), outcome assessment blinding (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias) and other biases. Possible ratings were ranked by risk: low (L); high (H); uncertain (U).

(2) Statistical analyses

When appropriate, data extracted was combined for meta-analysis using Review Manager 5.3. Effect size was estimated and reported as the mean difference (MD) for continuous variables with a 95% confidence interval (CI). Weight was calculated in individual studies based on the inverse of variance. This study used a random-effects model for analyses due to expected heterogeneity of the studies selected. Study statistical homogeneity was assessed using a Cochran test and by examining the observed variances in effect sizes and residual variance. I^2 was calculated to quantify heterogeneity. $I^2 > 50\%$ was considered significant [10]. No statistical corrections were used to adjust for multiple analyses.

According to Cochrane reviews [10], in meta-analysis, studies with baseline changes as outcomes could be combined with those with final measurements as outcomes. In randomized trials, differences in mean values obtained from baseline changes were usually analyzed on the basis of final measurements and obtained the same effects. In this meta-analysis, baseline changes and final measurements from different studies were combined.

The reason of disagreement from previous studies about ultrasonic and manual subgingival scaling might be that they did not compare them in the same initial pocket depth. In other words, they did not control the variate of initial PPD. So, in this study, we established three subgroups based upon initial pocket depth: shallow ($\leq 4\text{mm}$); medium (4–6mm); and deep ($\geq 6\text{mm}$), to eliminate the effect of the initial PPD to the result.

If a study had two initial PPD groups that could be included in one subgroup, data was combined to conform to the depth classification, using the formulas in Table S2 [10].

Results

Study selection

There were 1,434 studies searched. References in selected papers were searched and no additional studies were located. After reading full texts, ten studies were finally selected. Process selection appears in Figure 1.

There were 495 duplicates in the 1,434 studies. 875 studies were ruled out after reading titles and abstracts. Another 43 studies were ruled out after reading the full text. There were 11 unavailable or awaiting classifications. Finally, 10 studies were included. Studies eventually included were from 2004 to 2015.

Study characteristics

All research included were RCTs. Follow-up periods were 3 and 6 months. Characteristics of articles selected for primary outcomes appear in Table 1. Characteristics of articles selected for secondary outcomes appear in Table 2. Reasons for study exclusion appear in

Table S3.

Limited information of 11 studies could be obtained from the publication. Inclusion, or exclusion could not be decided because of unobtainable full texts and unknown specific conditions. These appear in Table S4.

Quality and risk of bias assessment

Bias analysis results for the studies appear in Figures S1 and S2. Most studies did not have high bias risks. Funnel plots could not be done due to limited number of studies (<10).

Meta-analysis Results of Primary Outcomes

The follow-up period lengths of the studies varied. Most were 3 and 6 months. This allowed for grouping into 3- and 6-months and reduced heterogeneity.

Outcome 1 \square PPD

(1) 3 months:

a) Initial PPD \leq 4mm

Only one met the criteria, which reported no statistical differences between ultrasonic and manual subgingival scaling[11].

b) Initial PPD >4mm

When initial PPD was medium, differences between ultrasonic and manual subgingival scaling were statistically significant (Fig. 2A). PPD reduction after manual subgingival scaling was greater than ultrasonic instruments(MD 0.14 \square 95% CI [0.02, 0.26], P = 0.02). Heterogeneity was great (Tau² = 0.01; Chi² = 28.94, df = 3 (P < 0.00001); I² = 90%).[11–14]

When initial PPD was deep, heterogeneity was acceptable (Tau² = 0.01; Chi² = 4.24, df = 3 (P = 0.24); I² = 29%). PPD reduction after the two treatments were not statistically significant (MD 0.13, 95%CI [-0.02, 0.28], P = 0.09). [11–13, 15]

(2) 6 months:

a) Initial PPD \leq 4mm

Two studies [11, 16] met the criteria as they used baseline changes as outcomes and one baseline changes value of 0. A meta-analysis could not be done using the two studies. They both reported no statistical differences between ultrasonic and manual subgingival scaling.

b) Initial PPD >4mm

When initial PPD was medium, differences between ultrasonic and manual subgingival scaling were not statistically significant (MD 0.19, 95%CI [0.11, 0.27], P = 0.22). Heterogeneity was large (Tau² = 0.02; Chi² = 25.89, df = 3 (P < 0.0001); I² = 88%). [11, 14, 16, 17](Fig. 2B)

When initial PPD was deep, heterogeneity was also great (Tau² = 0.08; Chi² = 8.74, df = 3 (P = 0.03); I² = 66%). PPD reduction after manual subgingival scaling was greater than ultrasonic instruments with a statistically significant difference (MD 0.50, 95%CI [0.10, 0.89], P = 0.01).[11, 15–17]

Outcome 2 \square CAL

(1) 3 months:

a) Initial PPD \leq 4mm

Only one met the criteria, reporting no statistically significant difference between the two methods [11].

b) Initial PPD >4mm

When initial PPD was medium, differences between ultrasonic and manual subgingival scaling were not statistically significant (MD -0.08, 95%CI [-0.18, 0.03], P = 0.14). Heterogeneity was great ($\text{Tau}^2 = 0.01$; $\text{Chi}^2 = 10.92$, df = 3 (P = 0.01); $I^2 = 73\%$). [11–14] (Fig. 2C)

When initial PPD was deep, difference between ultrasonic and manual subgingival scaling was not statistically significant (MD -0.06, 95%CI [-0.58, 0.46], P = 0.81). Heterogeneity was also high ($\text{Tau}^2 = 0.16$; $\text{Chi}^2 = 23.28$, df = 3 (P < 0.0001); $I^2 = 87\%$) [11–13, 15].

(2) 6 months

a) Initial PPD ≤4mm

The heterogeneity of the two studies was too large ($\text{Tau}^2 = 0.10$; $\text{Chi}^2 = 10.55$, df = 1 (P = 0.001); $I^2 = 91\%$) for a meta-analysis to be performed. They both indicated no statistically significant differences between ultrasonic and manual instruments [11, 16]. (Fig. 2D)

b) Initial PPD >4mm

No statistically significant differences were found between the ultrasonic and manual subgingival scaling when initial PPD was medium (MD -0.06, 95%CI [-0.17, 0.06], P = 0.33). Heterogeneity was slightly great ($\text{Tau}^2 = 0.01$; $\text{Chi}^2 = 6.29$, df = 3 (P = 0.10); $I^2 = 52\%$). [11, 14, 16, 17] (Fig. 2E)

At deep pocket depths, differences between the two were not statistically significant (MD 0.28, 95%CI [-0.20, 0.77], P = 0.26). Heterogeneity was large ($\text{Tau}^2 = 0.15$; $\text{Chi}^2 = 10.37$, df = 3 (P = 0.02); $I^2 = 71\%$). [11, 15–17]

Secondary outcome measures

(1) *GRIS* Sculean et al. [17] indicated no statistical differences studying single or multiply-root teeth between ultrasonic and manual subgingival scaling at 6-months when initial PPD was deep. Kargas et al. [14] noted that, at medium depths, there were no statistical differences between ultrasonic and manual subgingival scaling at either 3 or 6-months.

(2) *BOP*: Christgau et al. [16] found that at 6-months, manual subgingival scaling showed greater BOP reduction at initial deep pocket depth compared to ultrasound.

(3) *Residual dental calculus*: Schwarz et al. [18] indicated that for single-root teeth at deep initial depth, ultrasonic subgingival device was superior to manual instruments in removing subgingival dental calculus. Yukna et al. [19] found no statistical differences in residual dental calculus rates between ultrasonic and manual subgingival scaling with initial PPD at 5–6mm, 7–8mm or > 9mm. Gellin et al. [20] found no statistical differences in dental calculus clearance rates between the two methods when initial PPD was 0–3mm, 4–5mm, or 6–12mm. When ultrasonic subgingival scaling was combined with manual instruments, the effectiveness was superior to either ultrasonic or manual instruments individually [20].

Sensitivity analysis

Outcome: PPD

At 3-months, at medium depth, heterogeneity was great ($I^2 = 90\%$). After sensitivity analysis, four studies were found highly heterogeneous to each other and were unsuitable for meta-analysis. After a bias analysis, the heterogeneity source was thought to be: (1) small number of studies; (2) the fact that tissue healing took time and early probing disrupted attachment gains. At 3-months, PPD and CAL reductions were unstable, causing large heterogeneity.

At medium depth, 6-months, Kargas et al. [14] found significant heterogeneity. After excluded, heterogeneity decreased to 0% ($\text{Tau}^2 = 0.00$; $\text{Chi}^2 = 0.02$, df = 2 (P = 0.99); $I^2 = 0\%$). The results showed statistically significant differences between manual and ultrasound groups. PPD reduction after manual subgingival scaling was greater than ultrasonic subgingival scaling (MD 0.19, 95%CI [0.11, 0.27],

$P < 0.00001$). Compared with the other three studies, only non-smokers were included in this study, which might be the reason for heterogeneity.

When initial PPD was deep at 6 months, D'Ercole [15]. was a major origin of heterogeneity ($\text{Tau}^2 = 0.03$; $\text{Chi}^2 = 3.86$, $\text{df} = 2$ ($P = 0.15$); $I^2 = 48\%$) After exclusion, heterogeneity decreased to 48% (Fig. 3A).

Outcome \times CAL

When initial PPD was medium, at 3-months follow-up, the heterogeneity of CAL was high ($\text{Tau}^2 = 0.01$; $\text{Chi}^2 = 10.92$, $\text{df} = 3$ ($P = 0.01$); $I^2 = 73\%$). According to a sensitivity analysis, four studies were highly heterogeneous with each other, making them unsuitable for meta-analysis (Fig. 3B). The same argument applies to a 3-month follow-up when initial PPD was medium: (1) too few studies; (2) tissue healing took time and early intervening probing may damage attachment gain. When the follow-up period was only 3 months, CAL were unstable which caused great heterogeneity.

Heterogeneity was also large in the following three groups: 1) deep pocket, at 3-months follow-up; 2) medium and deep pockets, at 6-months follow-up [11]. After excluding this study [11], heterogeneity decreased from: 87%; 52%; and 71%, to 24%; 0%; and, 0%. This study was the only one in which 50% of the patients were smokers, while other papers were unclear about the ratio of smokers or had a small number of smokers, which might be the reason for heterogeneity. After exclusion, at a 6-month follow-up, after ultrasonic scaling, CAL reduction was more than manual subgingival scaling and were statistically different. (MD 0.58, 95%CI [0.27, 0.89], $P = 0.0002$) (Fig. 3C).

Discussion

According to the above analysis, different indicators showed statistical significance between ultrasonic and manual subgingival scaling, which indicated the difference in clinic after the treatment of ultrasonic and manual instruments.

In the same study, heterogeneity of PPD and CAL was much greater at 3-months than at 6-months follow-up. The influence was quite apparent at medium PPD, 3-months. At deep PPD, either 3-months or 6-months, heterogeneity was acceptable. The reason could be that the tissue had took time to heal. In deep pockets, tissue contacted and attached to the bone better, resulting in shorter healing time and more stable within 3 months. At medium pocket depths, tissue did not contact bone as readily as at deeper pockets, so healing time was longer. Probing too early in healing process may damage tissue and influence attachment gain, and led to unstable results.

Sensitivity analysis suggested that too few articles (1–2) met the requirement of shallow initial PPD. This meant that no reliable conclusions could be reached and more studies should be required. After excluding a major source of heterogeneity, according to the sensitivity analysis, the deep initial PPD at 3-month follow-up and all data from the 6-month follow-up were analyzed and following results were returned:

A. 3-month follow-up, at deep pocket:

PPD and CAL reductions showed no differences between ultrasound and manual groups.

B. 6-month follow-up:

a) for shallow initial PPD, no conclusion could be drawn because of limited articles;

b) at medium initial PPD, PPD reduction showed manual instruments better. CAL reduction showed no differences between ultrasound and manual groups;

c) at deep initial PPD, PPD and CAL indicated manual subgingival scaling was superior.

In addition, in shallow pocket, CAL increased after both ultrasonic and manual subgingival scaling, which might be resulted from junctional epithelium attachment damage [16]. We have also found it clinically. Therefore, manual subgingival scaling is not recommended when PPD is less than 4mm. In clinical practice, when PPD is less than 4mm and there is symptom such as bleeding on probing or subgingival dental calculus, ultrasonic subgingival working tip can be used for deep cleaning.

In terms of GR, at medium or deep PPD, there was no differences between manual and ultrasonic subgingival scaling, whatever the roots were single or multiple. [14, 17]

BOP results of one study [16] showed, at 6-months follow-up, more BOP reduction at deep depths after manual scaling than ultrasound.

Residual calculus provided different results. Two studies [19, 20] indicated that, regardless of depth, there were no statistical differences in calculus clearance rates between ultrasound and manual treatment. Schwarz [18] indicated when PPD was deep, for a single-root tooth, ultrasonic dental calculus removal was more effective than manual subgingival scaling.

Above all, ultrasonic subgingival scaling is an effective non-surgical treatment [6], yet manual subgingival scaling is also essential and cannot be replaced by ultrasonic method.

According to the newly-released 2018 periodontitis classifications, there are something about it:

1. different economic and health care developments between developed and developing countries make different influences on periodontitis [21, 22]. Primary CAL in developing countries was three times of developed countries[22]. Only one study [12] involved a developing country (Turkey). Whether the conclusions reached in this paper apply to developing countries is unknown.
2. Smoking is confirmed as affecting progress of periodontitis and was considered in the new classification [21]. Most of the included studies chose patients according to the 1999 classification and did not consider the impact of smoking, which may lead to heterogeneity.

Summary:

1. Significance to clinical practice

(1) It may be premature to probe within 3 months after therapy. It may lessen attachment gain, slow or interrupt recovery and lead to inaccurate measurements. Therefore, only 6-month follow-up results are used to reach following conclusions:

- a) When initial PPD was shallow, no conclusions were drawn due to the limited number of studies.
- b) When initial PPD was medium, PPD reductions proved that manual subgingival scaling was superior. CAL and GR results showed no statistical differences. More studies are needed before any conclusion can be drawn.
- c) When initial PPD was deep, manual subgingival scaling was superior in terms of PPD reduction, CAL and BOP, while GR results showed no statistical differences. This conclusion also needs more study because of the limited number of studies.

(2) In terms of residual dental calculus, there was no conclusion could be drawn.

2. Significance to research

- (1) Inclusion and exclusion criteria could refer to the new classification to reduce bias;
- (2) Studies should consider other indicators such as BOP, PI, and GI, bacterial changes, when comparing in different PPDs;
- (3) More studies are needed in developing countries;
- (4) Single and multiple root teeth should be measured separately;
- (5) Further studies should enlarge sample sizes to improve credibility;
- (6) Inclusion or exclusion criteria for smokers should be standardized.

Conclusions

Results varied between ultrasonic and manual subgingival scaling on different initial PPDs: (1) the limited number of studies of shallow initial PPDs allowed for no conclusion; (2) when initial PPD was medium, PPD reduction proved manual subgingival scaling superior, but CAL and GR reduction showed no statistical differences; (3) when initial PPD was deep, PPD and CAL reductions and BOP results suggested that manual subgingival scaling was superior to ultrasonic subgingival scaling, while GR reduction showed no statistical differences between the two methods. No conclusion could be drawn about residual dental calculus.

Suggestions: when initial PPD is medium or deep, use ultrasonic and manual subgingival instruments together.

In conclusion, ultrasonic subgingival scaling is an effective non-surgical treatment of periodontitis. Meanwhile, manual subgingival scaling is also significant and cannot be completely replaced by ultrasonic scaling.

Declaration

1) Ethics approval and consent to participate (not applicable for that section).

2) Consent for publication (not applicable for that section).

3) Availability of data and material: We declared that materials described in the manuscript, including all relevant raw data, will be freely available to any scientist wishing to use them for non-commercial purposes, without breaching participant confidentiality.

4) Competing interests: The authors declare that they have no competing interests.

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6) Authors' contributions:

Zhang Xin, Hu Zixuan and Zhu Xuesong contributed equally. Zhang Xin, Hu Zixuan and Zhu Xuesong designed the work with Li Wenjie and Chen Jun. And Zhang, Hu and Zhu finished the acquisition, analysis and interpretation of data. Then Zhang, Hu and Zhu have drafted the work and revised it under the guidance of Chen and Li. Each author have approved the submitted version (and any substantially modified version that involves the author's contribution to the study), and have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Tables

Table 1. Included studies characteristics (Primary outcome measures)

Study	First Author, Year Outcomes Mean age (\pm SEM) Female/Male Country	PPD	Interventions	Follow Up	Inclusion criteria	Exclusion criteria	Smoker/Non-smokers ratio
Pilot study on the clinical and microbiological effect of subgingival glycine powder air polishing using a cannula-like jet	- Kargas, K.2015 - PPD, CAL - 52.50 \pm 9.54 - 12/15 - Greece	moderate pockets	ultrasonic instrumentation (Piezonâ, Instrument A, EMS, Nyon, Switzerland) hand instruments (Gracey currettes 3/4, 11/12, 13/14, Hu-Friedy, Chicago, IL, USA)	6 Months	(a) Must have been previously diagnosed with generalized chronic periodontitis (according to American Academy of Periodontology) and successfully treated; (b) Subsequently, entered the supportive treatment phase (SPT), with at least two non-bleeding residual pockets >4 mm in each quadrant; (c) Have at least 20 natural teeth; (d) Non-smoker; (e) Could not taken an antibiotic, anti-inflammatory medication, corticosteroids or other immunosuppressive drugs during the previous 6 months; (f) Pregnant or lactating women were also excluded from this study.	None	No smoker
Er:YAG lasers versus ultrasonic and hand instruments in periodontal therapy: clinical parameters, intracrevicular micro-organism and leukocyte counts	- Malali, E.2012 - PPD, CAL - 48.83 \pm 7.23 - 11/19 - Turkey	4-6mm, >7mm	a magnetostrictive ultrasonic scaler (Cavitron Bobcat Pro, Dentsply International Inc, USA) manual periodontal currettes (Gracey, SG # 5/6, 7/8, 11/12, 13/14, Mini Five Gracey SAS # 5/6, 11/12, Hu-Friedy Ins. Co., USA)	3 Months	Patients with generalized periodontal breakdown and who had at least four single-rooted teeth, two moderately deep (probing depth [PD] of 4-6mm) and two deep pockets (PD \geq 7mm) that had no endodontic lesion and no crown, with mobility 0-2, and with bleeding on probing (BOP) were selected.	(a) Periodontal treatment within the last 6 months; (b) Any systemic disease that would influence the periodontal tissues; (c) Antibiotic used within last 6 months; (d) Pregnancy and smoking.	No smoker
Hand instrumentation versus ultrasonic debridement in the treatment of chronic periodontitis: a randomized clinical and microbiological trial	- Ioannou, I.2009 - PPD, CAL - SRP:49.62 \pm 2.07 UD 50.47 \pm 2.58 - SRP:50/50 UD:70.6/29.4 - Greece	<4mm, 4-6mm, >6mm	UD: (EMS Piezon®, EMS, Nyon, Switzerland) with A and P instruments (Swiss Instruments PM, EMS) under water irrigation SRP: Hu-Friedy Gracey Standard Currettes SG 3/4, 11/12, 13/14, After Five® Currettes SAS 3/4, 11/12, 13/14, Hu-Friedy.	3 Months, 6 Months	(a) Existence of a minimum of four sites with PPD 5 mm in at least two quadrants of each of the patients, demonstrating bleeding on probing; (b) No periodontal treatment during the previous 6 months.	(a) Compromised medical condition; (b) Systemic antibiotics during treatment or for the last 3 months; (c) Ongoing drug therapy that might affect periodontal therapy; (d) Requirement for prophylactic antibiotic cover of the patient; (e) Use of chlorhexidine mouthwash or any other antimicrobial agent; (f) Pregnancy for female patients.	SRP: 50% of patients is smoker; UD: 52.9% of patients is smoker.
Non-surgical periodontal	- Sculean, A. 2004 - PPD, CAL	4-6mm, >6mm	VUS: Vector probe, (Durr Dental,	6 Months	(a) No treatment of periodontitis for the	None	Unclear

treatment with a new ultrasonic device (Vector™ - ultrasonic system) or hand instruments a prospective, controlled clinical study	- 54 - 24/14(VUS:10/9;SRP:11/8) -Germany		Bietigheim-Bissingen,Germany) using straight and curved metal curettes and a polishing fluid (HA particles <10um) according to the instructions given by the manufacturer SRP:Hand instruments (Gracey Curettes, HuFriedy Co., Chicago, IL, USA).		last 2 years; (b) No use of antibiotics for the 12 months prior to treatment; (c) No systemic diseases, and (d) Good level of oral hygiene. As criterion for a good level of oral hygiene a mean plaque index (PI) score <1 was chosen.		
Periodontal healing after non-surgical therapy with a modified sonic scaler: A controlled clinical trial	- Christgau, M. 2006 - PPD, CAL - 45.6±8.0 - 14/6 - Germany	<4mm, 4-6mm, >6mm	UD:the modified sonic scaler system SonicFlex 2003L (KaVo) SRP:Gracey-curettes #1/2, #7/8, #11/12, #13/14, HuFriedy, Chicago, IL, USA.	6 Months, 1 Month(excluded)	All had generalized moderate to progressive chronic periodontitis, but were systemically healthy and had not received systemic antibiotics for at least 3 months before. Each patient had to show at least four teeth per quadrant with a PPD of at least 4 mm.	None	14/6
Full-mouth ultrasonic debridement versus quadrant scaling and root planing as an initial approach in the treatment of chronic periodontitis*	- Wennström, J. L. 2005 - PPD, CAL - 25-75 years old, mean age 49.8 - 19/22 SRP11/10; UD8/12 - Italy, Sweden	5-6mm, 7mm	UD:EMS Piezon Master 400 with A+PerioSlim tips, water coolant and power setting to 75%; EMS, Nyon, Switzerland SRP:LM-dental, Turku, Finland.	3 Months, 6 Months	(a) A minimum of 18 teeth; (b) At least eight teeth must show probing pocket depths (PPD) of 5 mm and bleeding on probing (BOP). At least two of these teeth must have a PPD of 7 mm and at additional two teeth, the pockets must measure 6 mm; (c) Unremarkable general health according to medical history and clinical judgement; (d) Female patients must not be pregnant.	(a) Subgingival instrumentation within 12 months prior to the baseline examination; (b) The use of antibiotics within 3 months prior to the start of the study; (c) Compromised medical conditions requiring prophylactic antibiotic coverage; (d) Ongoing drug therapy that might affect the clinical signs and symptoms of periodontitis.	Italy: UD 4/11, SRP 4/10, Sweden: UD 7/10, SRP 6/11
Effectiveness of ultrasonic instruments in the therapy of severe periodontitis: a comparative clinical-microbiological assessment with curettes	- D'Ercole, S. 2006 - PPD, CAL - 40.8 ±3.9 - 11/7 - Unclear	≥6mm	UD:a power-driven mechanism(Vector® System) SRP: the type of manual instruments is unclear	3 Months, 6 Months, 1 Month(excluded)	(a) Positive for diagnosis of mild-to-severe chronic periodontitis; (b) Good general health according to their medical history; (c) Negative for the use of any antibiotic or antiinflammatory drugs within the three months preceding the beginning of the study; (d) Negative for periodontal therapy within 1 year preceding the beginning of the study; (e) Experimental sites (test and control) localized in	None	No-smoker

the interproximal position of two different teeth in the same subject (split-mouth design);
(f) Probing depth (PD) values equal to or more than 6 mm in the experimental sites;
(g) Difference of PD in the experimental sites (test and control) not exceeding 2 mm;
(h) Presence of at least ten teeth for each dental arch. Pregnant or nursing females were excluded from the study.

SRP, scaling and root planing with hand instrument; UD, ultrasonic debridement; PPD, probing pocket depth; CAL, clinical attachment level

*: The data is from two study centers: Italy and Sweden.

Table 2. Included studies characteristics (Secondary outcome measures)

Study	First Author, Year Outcomes Mean age (\pm SEM) Female/Male Country	PPD	Interventions	Follow Up	Inclusion criteria	Exclusion criteria	Smoker/Non- smokers ratio
Pilot study on the clinical and microbiological effect of subgingival glycine powder air polishing using a cannula-like jet	- [14] - GR - 52.50 \pm 9.54 - 12/15 - Greece	Moderate pockets	Ultrasonic instrumentation (Piezonâ, Instrument A, EMS, Nyon, Switzerland)¶ Hand instruments (Gracey cures 3/4, 11/12, 13/14, Hu-Friedy, Chicago, IL, USA)	6 Months	(a) Must have been previously diagnosed with generalized chronic periodontitis (according to American Academy of Periodontology) and successfully treated; (b) Subsequently, entered the supportive treatment phase (SPT), with at least two non-bleeding residual pockets >4 mm in each quadrant; (c) Have at least 20 natural teeth; (d) Non-smoker; (e) Could not taken an antibiotic, anti-inflammatory medication, corticosteroids or other immunosuppressive drugs during the previous 6 months; (f) Pregnant or lactating women were also excluded from this study.	None	No smoker
Clinical evaluation of the speed and effectiveness of subgingival calculus removal on single-rooted teeth with diamond-coated ultrasonic tips	- [19] - The mean percent of calculus remaining - Unclear - Unclear - America	5-6mm, 7-8mm	Hand cures, Plain ultrasonic	Extract the teeth after the treatment	Subjects had moderately deep probing depths (\geq 5 mm in depth), had not received scaling and root planing for at least 6 months prior to the study, and exhibited clinically and/or radiographically evident subgingival calculus on the study teeth.	None	Unclear
The effectiveness of the Titan-S sonic scaler versus cures in the removal of subgingival calculus. A human surgical evaluation	- [20] - The percentage of surfaces with residual calculus - Unclear - Unclear - America	<3mm, 4-5mm, 6-12mm	Ultrasonic instrument (Titan-S), Hand instrument (Gracey curette and the McCall's)	Extract the teeth after the treatment	Exhibit radiographic evidence of subgingival calculus or a clinically detectable ledge of subgingival calculus on at least one interproximal surface per quadrant, and have no systemic disease contraindicating periodontal therapy or the use of local anesthetics.	None	Unclear
Non-surgical periodontal treatment with a new ultrasonic device (Vector™ - ultrasonic system) or hand instruments a prospective, controlled clinical study	- [17] - GR, BOP - 54 - 24/14(VUS:10/9;SRP:11/8) -Germany	4-6mm, >6mm	UD: Vector probe.(Durr Dental, Bietigheim-Bissingen,Germany) using straight and curved metal cures and a polishing fluid (HA particles <10um) according to the instructions given by the manufacturer¶ SRP:Hand instruments (Gracey Cures, Hu-Friedy Co., Chicago, IL, USA).	6 Months	(a) No treatment of periodontitis for the last 2 years; (b) No use of antibiotics for the 12 months prior to treatment; (c) No systemic diseases; (d) Good level of oral hygiene. As criterion for a good level of oral hygiene a mean plaque index (PI) score <1 was chosen.	None	Unclear
Periodontal	- [16]	<4mm, 4-	UD:the modified sonic	6 Months, 1	All had generalized	None	14/6

healing after non-surgical therapy with a modified sonic scaler: A controlled clinical trial	- BOP, GR - 45.6±8.0 - 14/6 - Germany	6mm, >6mm	scaler system SonicFlex 2003L (KaVo) SRP: Gracey-curettes #1/2, #7/8, #11/12, #13/14, HuFriedy, Chicago, IL, USA.	Month(excluded)	moderate to progressive chronic periodontitis, but were systemically healthy and had not received systemic antibiotics for at least 3 months before. Each patient had to show at least four teeth per quadrant with a PPD of at least 4 mm.
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Influence of fluorescence-controlled Er:YAG laser radiation, the Vector™ system and hand instruments on periodontally diseased root surfaces in vivo	- [18] - The roughness of cementum surface - 44.8 - 7/5 - Germany	>6mm	UD: ultrasonic system (Vector™, Dürr, Bietigheim-Bissingen, Germany) and a polishing fluid (hydroxylapatite particles <10 µm) was used according to the instructions given by the manufacturer (70% power setting). SRP: Gracey curettes (Hu-Friedy Co., Chicago, IL, USA)	Extract the teeth after the treatment	(a) Probing pocket depths (>6 mm) on at least two aspects (mesio-buccal/mesio-lingual and disto-buccal/disto-lingual) as measured from the gingival margin to the bottom of the pocket; (b) No signs of carious or artificial damage on the root surface; (c) No periodontal root surface treatment within the last 12 months; (d) No root fractures or anatomical abnormalities.	Patients suffering from systemic diseases were excluded from the study.	Unclear
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SRP, scaling and root planing; UD, ultrasonic debridement; GR, gingival recession; BOP, bleeding on probing.

Table 3. Abbreviations

Abbreviations	Term
AL	Attachment level
BOP	Bleeding on probing
CAL	Clinical attachment loss
GR	Gingival recession
MD	Mean depth
PPD	Probing pocket depth

Figures

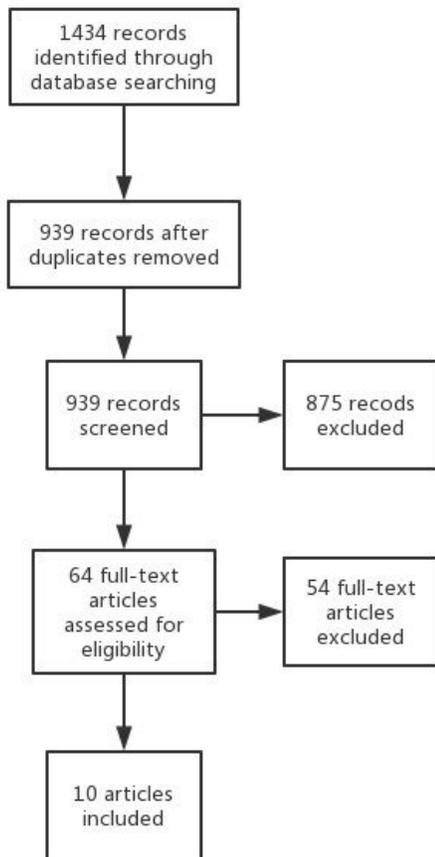


Figure 1

Selection process PRISMA flow chart

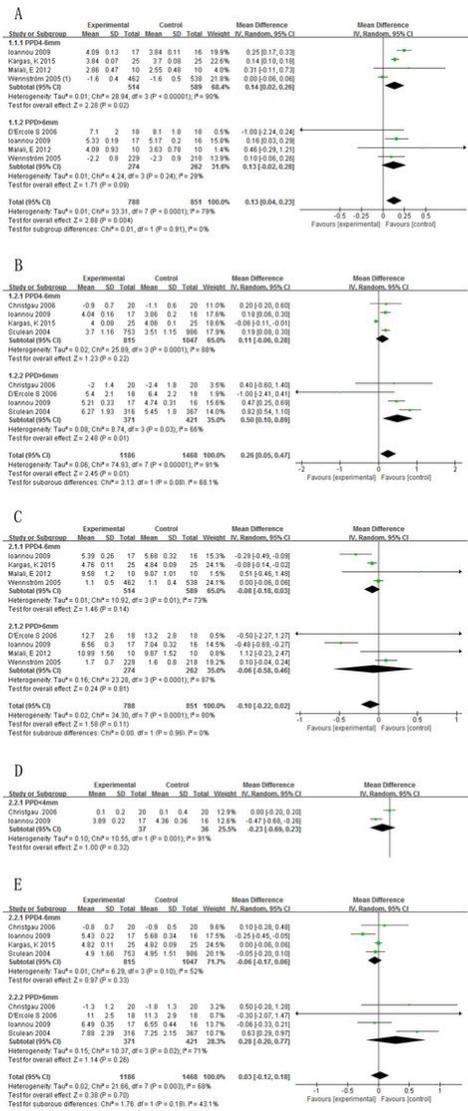


Figure 2

A. Forest plot comparing PPD at 3-months with manual subgingival scaling versus ultrasonic subgingival scaling of initial PPD > 4mm in terms of the following: 1.1.1 PPD4-6mm; 1.1.2 PPD ≥ 6mm B. Forest plot comparing PPD at 6-months with manual subgingival scaling versus ultrasonic subgingival scaling of initial PPD > 4mm in terms of the following: 1.2.1 PPD4-6mm; 1.2.2 PPD ≥ 6mm C. Forest plot comparing CAL at 3-months with manual subgingival scaling versus ultrasonic subgingival scaling of initial PPD > 4mm in terms of the following: 2.1.1 PPD4-6mm; 2.1.2 PPD ≥ 6mm D. Forest plot comparing CAL at 6-months with manual subgingival scaling I versus ultrasonic subgingival scaling of initial PPD were shallow in terms of the following: 2.2.1 PPD ≤ 4mm. E. Forest plot comparing CAL at 6-months with manual subgingival scaling versus ultrasonic subgingival scaling of initial PPD > 4mm in terms of the following: 2.2.1 PPD4-6mm; 2.2.2 PPD ≥ 6mm.

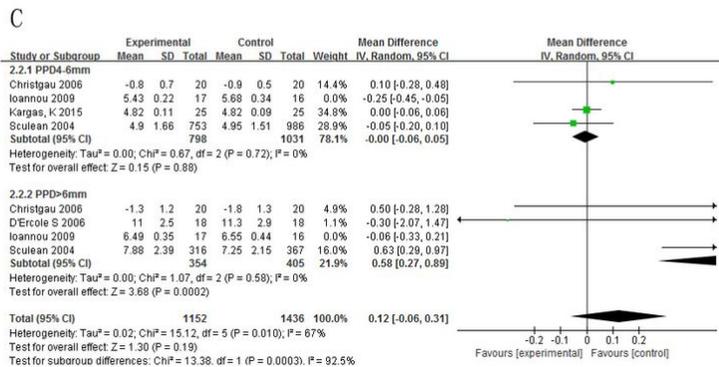
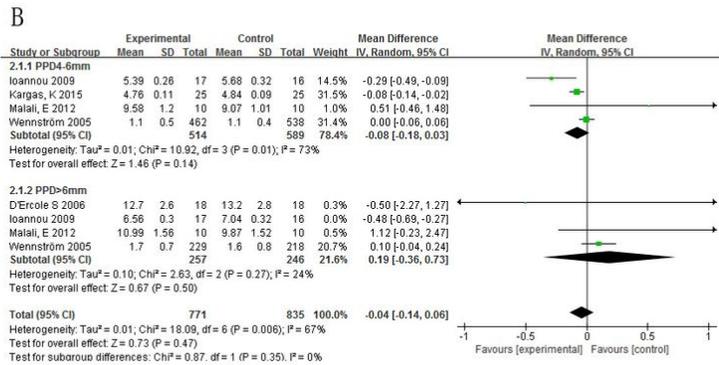
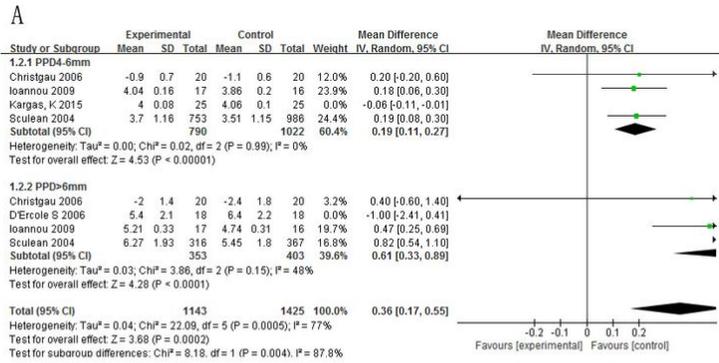


Figure 3

A. Sensitivity analysis of PPD at 6-months in terms of the following: 1.2.1 PPD < 6mm; 1.2.2 PPD ≥ 6mm. B. Sensitivity analysis of CAL at 3-months in terms of the following: 2.1.1 PPD < 6mm; 2.1.2 PPD ≥ 6mm. C. Sensitivity analysis of CAL at 6-months in terms of the following: 2.2.1 PPD < 6mm; 2.2.2 PPD ≥ 6mm.

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