1 **Surgical therapy for peri-implantitis management: a systematic review and meta-analysis**

2 *Abbreviated running title*: Surgical peri-implantitis management

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Abstract

Aim: Peri-implantitis is a common cause of late implant failure. Studies have investigated different treatment strategies. The effectiveness of these modalities, however, remains unclear. This study aimed to evaluate the success of surgical peri-implantitis treatment using clinical and radiographic parameters.

Material and methods: A systematic review of published literature was employed. Key words were selected to conduct an electronic search using four databases for literature on human clinical studies. Meta-analyses were carried out for clinical probing, pocket depth and radiographic bone level.

Results: A total of 16 papers met the inclusion criteria. Four treatment modalities to supplement mechanical debridement were identified: 1) apically-repositioned flap, 2) chemical surface decontamination, 3) implantoplasty and, 4) bone augmentation. Inconsistent results were evident which were dependent on several treatment-independent factors. No clinical benefits were identified for the additional use of surface decontamination, while limited evidence demonstrated improvement of clinical and radiographic outcomes after implantoplasty. The effect of bone augmentation appeared limited to 'filling' radiographic defects.

Conclusions: The outcomes of the currently available surgical interventions for peri-implantitis remain unpredictable. There is no reliable evidence to suggest which methods are the most effective. Further randomised-controlled studies are needed to identify the best treatment methods.

53 **Clinical Relevance**

54 Scientific rationale for study: In the management of patients with peri-implantitis, the treatment

55 of established bony defects around fixtures remains a significant clinical challenge. Principal

56 findings: Whilst a range of surgical treatment modalities have been described, from simple

57 debridement to implantoplasty and attempted guided-tissue regeneration, the individual techniques

58 employed often appear based on operator-preference. Practical implications: This systematic review

59 sought to evaluate the existing evidence to compare the existing surgical treatment modalities,

60 determine their effectiveness and inform the management of these patients, however, the

61 outcomes remain unpredictable. Further studies are required to discover the optimal surgical

62 treatment approach for peri-implantitis.

63

64 **Introduction**

65 Implants provide a long-term, generally predictable treatment to restore function [1], aesthetics [2],

66 self-esteem [3], and quality of life [4] following tooth-loss. The application and use of dental implants

67 has increased and now represents an indispensable therapeutic option for the replacement of

68 missing teeth.

69 Peri-implantitis is considered to be the main biological cause of 5-year implant failure [5, 6].

70 Review studies have estimated that peri-implantitis will affect 28%-56% of patients and 12%–43% of

71 individual implant sites [7, 8]. This variation in prevalence may reflect differences in study design,

72 population size and risk profiles, and the clinical 'definition' of peri-implantitis [7, 9]. There remains a

73 lack of evidence regarding treatment and prognosis of peri-implantitis [8].

74 The inflammatory destruction of peri-implant tissue is multi-factorial. However, biofilm and

75 bacterial infection are considered to be the major aetiological features in the development of peri-

76 implant disease [8]. Smoking is also a strong predictor of implant failure [10], leading to an increase in

77 prevalence that is 4.7 times greater than is observed in non-smokers [11] . Implant failure is 6 times

78 greater in patients with a history of periodontitis than those who did not have a history of

79   periodontitis [11]. Systemic risk factors such as diabetes, cardiovascular diseases, age, gender, and

80   genetics have been suggested as potential risk factors, although studies are limited [12, 13]. Local risk

81   factors, e.g. excess cement, was associated with signs of peri-implantitis in 100% of patient with a

82   history of periodontal disease and 65% of healthy controls [14].

83   The diagnosis of peri-implantitis depends on the presence of inflammatory signs, bleeding

84   on probing (BOP) or suppuration on probing (SOP) and the degree of bone loss evident

85   radiographically [15]. However, it is important to distinguish this diagnosis of peri-implantitis from

86   bone resorption resulting from bone remodelling which occurs early after implant placement [7].

87   Some authors do not consider peri-implantitis as a differential diagnosis unless the implants have

88   been in place for >12 months [16-18].

89   The consensus report of the *11th European Workshop on Periodontology* highlights steps to

90   reduce the risk of incidence of peri-implantitis [19]. The indications for appropriate management

91   strategies that appear in clinical studies have resulted in development of the 'cumulative

92   interceptive supportive therapy' [15, 20, 21]. The management of peri-implantitis is based on similar

93   techniques to those of periodontitis [11] which entail the elimination of inflammation and prevention

94   of further bone loss; including non-surgical (conventional) and surgical treatment [22]. Conventional

95   non-surgical treatment can be classified into mechanical, chemical and light-mediated therapies.

96   Reviews and meta-analyses have concluded that there is no reliable non-surgical treatment which

97   results in elimination of the disease [23-25].

98   Surgical treatment allows better access to the implant surface and the surrounding bony

99   defect [26] and is used in conjunction with patient-directed care, and non-surgical therapy to reduce

100   bacterial colonization and local inflammation [21]. Mechanical debridement of the implant surface can

101   be achieved using curettes, ultrasonic scalers, or air-abrasion, in the presence or absence of systemic

102   antibiotics. A 3-month follow-up study has shown that mechanical debridement alone, following

103   surgical access, is effective in reducing clinical/microbial parameters [27]. Whilst adjunctive surface

104   decontamination with antimicrobials such as chlorhexidine (CHX) reduced microbial counts, this had

105   no significant effect on clinical or radiographic parameters [28, 29]. Leonhardt et al. (2003) reported

106   that significant reduction in BOP and PPD (periodontal probing depth) following surgical

107   debridement and decontamination with H_2O_2[30]. Although many clinicians employ topical antibiotics

108   e.g. tetracycline and minocycline, their clinical effect remains unclear [31].

109   Lasers have been shown to have no additional clinical benefit as a potential surface-

110   decontamination agents during surgical therapy when compared with mechanical debridement [32, 33].

111   Photo-dynamic therapy (PDT) was shown to significantly decrease BOP and PPD between test and

112   control subjects in a randomised control trials (RCT), although the bacterial counts showed no

113   difference between the two groups [34].

114   Adjunctive resective surgery using osteoplasty, with or without apically re-positioned flap

115   (ARF) procedures, has been reported to improve clinical sign of peri-implantitis, where PPD ≥ 6 mm

116   were eliminated in 77% of subjects [35]. However, the use of ARF in the aesthetic zone is limited [11].

117   Implantoplasty is directed to reduce surface-roughness of the implant surface to decrease bacterial

118   and biofilm accumulation [36]. However, concerns have been raised regarding the reduction of implant

119   strength [37], deposits of titanium particles in the soft- and hard-tissues [38] and increased marginal

120   tissue recession and exposure of the implant surface [31]. Re-osseointegration using bone

121   augmentation (autogenous bone [39,40] and/or synthetic bone graft materials [41,42] may provide a

122   significant improvement in clinical and radiographic parameters compared to the baseline. Bone

123   graft (autogenous or synthetic), however, cannot be integrated on to a metal surface [43].

124   Furthermore, it has been shown that the use of membrane/s with autogenous or synthetic materials

125   has no additional benefit [40, 44].

126   The aim of this systematic review was to critically evaluate the current literature on the

127   surgical treatment of peri-implantitis and assess the effectiveness of treatment modalities (and

128   adjunctive therapies) on peri-implant and periodontal radiographic outcomes. The objective was to

129   identify the most predictable and reliable treatment modalities by a quantitative comparison of

130   outcomes using meta-analysis.

Materials and methods

Search Strategy

In order to achieve the aims of this study, an electronic literature search was conducted using Ovid MEDLINE, EMBASE and EBM Review – Cochrane Central Register of Control Trials and Cochrane Database of Systematic Reviews. The following keywords were combined: '*Tooth Implantation*' OR '*Dental Implants*' OR '*Tooth implants*' OR '*Oral Implants*' OR '*Endosseous implants*' OR '*Osseointegrated implants*' AND '*Periimplantitis*' OR '*Peri-implantitis*' OR '*Peri-implant disease*' OR '*Peri-implant defect*' OR '*Peri-implant infection*' OR '*Peri-implant inflammation*' OR '*Peri-implant bone loss*' AND '*Management*' OR '*Treatment*' OR '*Therapy*' AND '*Surgery*' OR '*Surgical*' OR '*Surgical approach*' OR '*Open flap*' OR '*Access flap*' OR '*Resective*' OR '*Regenerative*' OR '*Bone regeneration*' OR '*Bone augmentation*' (Table 1).

Study Selection Criteria

The criteria for inclusion of specific studies in this review were human studies published in the English language. Studies were selected for randomized controlled trials or prospective cohort studies only with ≥ 10 patients and ≥6 months follow-up (the longest follow up period was chosen in longitudinal studies which were published more than once). Experimental animal or studies *in vitro* were excluded.

Primary and secondary outcomes

The primary outcome for this review study was the reduction of BOP in implants treated surgically for peri-implantitis. The secondary outcomes were the assessment of PPD and RBL (radiographic bone loss).

Qualitative assessment methods (Risk of bias)

156   The modified 'Critical Appraisal Skills Program' (CASP) checklists was used to assess the quality of the

157   studies [45]. The risks of bias were categorized into; low risk (all the criteria were met), moderate risk

158   (1-2 criteria were missed) or high risk (>2 criteria were missed).

159

160   **Statistical Analysis**

161   Meta-analyses were conducted separately for the parameters PPD and RBL using computer software

162   (Stata® V13). All data used in meta-analysis were those measurements made at the end of the

163   observation period for both control and intervention arms. Forest plots were produced to represent

164   the standardized mean difference (SMD) between control and test groups. Pooled estimates and

165   associated 95% confidence interval (CI) from meta-analysis for each type of intervention were

166   indicated by 'diamond' symbols in Fig. 5; the center of the diamond (with respect to the x-axis)

167   indicates the pooled point estimate and the edges indicate the pooled 95% CI. I-squared values and a

168   chi-squared test were used to assess the heterogeneity of the studies.[46] Where heterogeneity was not

169   problematic fixed-effects meta-analysis was employed and random-effects meta-analysis was

170   otherwise employed. Although some evidence of an outlier was observed for RBL for some studies

171   [49,50], results for this study were included in Forest plots because it was not used to form any 'pooled'

172   estimates (it was the only study in the 'implantoplasty' group).

173

174   **Results**

175   **Literature on peri-implant disease**

176   Initial results highlighted the increase in published research on peri-implant disease over the last 15

177   years (Fig. 1a). There were significantly more publications on peri-implantitis and its surgical

178   treatment compared to the numbers of publications regarding peri-implant mucositis and non-

179   surgical treatment (Fig. 1b).

180

181   **Manuscript selection**

182 The literature search identified 320 studies, and 25 were selected for full-text evaluation following

183 title and abstract screening. A further 9 papers were excluded following careful review (Fig. 2), and

184 the remaining 16 studies included and reviewed for detailed qualitative and quantitative assessment

185 (see Supplementary Information for a summary of the included studies). Selection was based on the

186 'Preferred Reporting Items for Systematic review and Meta-Analysis' flow chart PRISMA [48]. Of the 16

187 studies included, 9 were RCTs, 4 were comparative prospective studies, and 3 were single group

188 prospective studies. The CASP checklist revealed that 53% of the included studies have a high risk of

189 bias, 35% have a moderate risk, and the remaining studies (12%) have a low risk of bias. The follow-

190 up periods of the studies that were included in the review ranged from 6 to 60 months. However,

191 the participants were observed for 12 months in most of the studies.

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195 **Surgical interventions**

196 The main type of surgical intervention was bone augmentation following mechanical debridement,

197 which was examined in 44% of the studies (Fig. 3a). The effect of mechanical debridement combined

198 with surface decontamination was examined in 38% of the studies. Relatively few studies (12%)

199 considered the effects of mechanical debridement only; 6% of the studies examined mechanical

200 debridement with implantoplasty. Xenograft materials were used for 64% of the bone augmentation

201 cases, whilst autogenous bone was used for 20% of the augmentation studies. CHX was the most

202 common surface decontamination method (57%) and was used in all of the cases (which included

203 debridement plus surface decontamination; Fig. 3b).

204

205 **Study outcomes**

206 The parameters used in clinical measurement of peri-implantitis were BOP, PPD, and RBL. The

207 majority of studies used both clinical and radiographic outcomes (69%), and the remaining studies

208 employed clinical parameters only (31%). Three studies [28, 29, 49] measured change in outcome

209 measurements with time (3, 6, and 12 months follow-up) and they showed that the mean BOP was

210 significantly decreased ($P < 0.05$) after 3 and 6 months followed by a gradual increase from 6 to 12

211 months (Fig. 4a). The mean PPD was also decreased significantly ($P < 0.05$) at 3-month follow-up

212 then remained relatively constant during the remaining periods (Fig. 4b). By contrast, RBL had not

213 increased significantly ($P > 0.05$) after 3 months.

214

215 **Meta-analysis**

216 The meta-analysis was conducted using 8 RCTs [28, 29, 32, 34, 50-53] and 2 controlled prospective cohort

217 studies [40, 44] as they reported mean reductions (and standard deviations) for PPD and RBL. The forest

218 plots for PPD and RBL are represented by the four methods for surgical peri-implantitis treatment

219 identified: 1) surface decontamination, 2) implantoplasty, 3) bone augmentation, and 4) additional

220 use of membranes in bone regeneration. Few studies have published data relating to BOP, and so no

221 meta-analysis could be conducted for this parameter.

222 Meta-analysis demonstrated that implants treated with surface decontamination had SMD of -0.21

223 (95% CI: -1.70 to 1.27) for PPD reduction. Only one study [50, 51] reported the effect of implantoplasty

224 on PPD reduction which shows a significant SMD of -3.33 (95% CI: -4.37 mm to -2.28 mm). Bone

225 augmentation with grafting materials and the additional use of membrane resulted in SMD of 0.15

226 mm (95% CI: -0.55 to 0.84 mm) and 0.30 mm (95% CI: -0.31 to 0.91 mm) respectively (Fig. 5a). In

227 terms of RBL changes, the use of surface decontamination methods resulted in SMD of 0.54 mm

228 (95% CI: -0.20 to 1.28 mm). Whereas implant treated with implantoplasty, had SMD of -3.38 (95% CI:

229 -4.43 to -2.33 mm). The SMD for RBL changes after the use of bone augmentation was -1.50 (95% CI:

230 -0.80 to -0.31 mm). However, the additional use of membrane has SMD of -0.16 (95% CI: -0.56 to

231 0.24 mm) (Fig. 5b). Whilst implantoplasty and bone augmentation resulted in significant

232 improvement in RBL, the use of surface decontamination or additional membrane application failed

233 to significantly affect observed treatment outcomes.

234   Heterogeneity was found to be small or moderate for the additional membrane subgroup

235   (i.e.: RBL, I-squared = 0.0%, P = 0.64; PPD, I-squared = 52.1%, P = 0.152) and so random-effects meta-

236   analysis should provide a reasonable pooled estimates in this case. Heterogeneity was found to be

237   high for the surface decontamination subgroup (i.e.: RBL, I-squared = 88.6%, P < 0.001; PPD, I-

238   squared = 97.1%, P < 0.001). A sensitivity analysis for RBL and for the additional membrane subgroup

239   could not be carried out for due to the small number of studies in this case. A sensitivity analysis

240   could be carried out for PPD for this subgroup, where removal of the study with the smallest sample

241   size of seventeen subjects in total (namely, Schwartz et al., 2013) did not affect pooled results very

242   greatly (i.e., SMD = -0.253 and 95% CI = -2.001 to 1.494), whereas removal of the only "outlying"

243   study that indicated a positive mean difference (namely, de Waal et al., 2015) did affect pooled

244   results (i.e., SMD = -0.866 and 95% CI = -1.663 to -0.069). This result indicates a significant reduction

245   in PPD for surface decontamination subgroup in this circumstance, although caution should still be

246   exercised due to the small number of studies and heterogeneity. Again, funnel plots are likely to

247   yield limited information only due to the small number of the studies included in the analysis.

248

249   **Discussion**

250   This systematic review and meta-analysis was conducted to explore the literature relating to the

251   surgical management of peri-implantitis. It was evident that the patient selection criteria for entry

252   into the studies (and the definition of 'peri-implantitis') varied considerably between the included

253   studies. For example, one study defined peri-implantitis by implants with RBL indicating >50% of

254   bone loss [40], whereas other studies defined peri-implantitis as affecting implants that exhibited PPD

255   >6mm with radiographically visible bony defects [32, 54, 55].

256   Radiographic interpretation of results was found to be inconsistent. Defect configuration

257   needs to be taken into account, and this is particularly evident where bone regeneration is to be

258   attempted using guided bone regeneration [55]. Roccuzzo et al. (2016) went on to show that the

259   circumferential defects showed better bone regeneration compared with the other types of defect.

260   However, another four-year study which included combined surgical therapy, surface

261   decontamination, and implantoplasty revealed that the outcomes were not directly affected by the

262   defect configuration [32].

263   Plaque control is pivotally important in peri-implant disease and response to treatment [15].

264   Adequate oral hygiene maintaining plaque scores at lower levels (PI ≤ 1) was important for reducing

265   the incidence of BOP [56]. The severity of peri-implantitis at the commencement of treatment (as

266   measured by the PPD and RBL) may clearly influence treatment outcomes [35, 57]. Other important

267   plaque-retentive factors, e.g. surface roughness are an important consideration when conducting

268   comparative studies [49, 53, 54]. A history of both smoking and periodontitis has been shown to have an

269   adverse effect on the treatment of peri-implantitis [44, 52, 58]. Due to the small numbers of patients,

270   variation in tobacco usage, and incomplete assessment of the severity of the previous periodontal

271   disease in the papers included within this study, this correlation could not be linked to the outcomes

272   of surgical peri-implantitis treatment.

273   The definition of a successful treatment also varied between studies. In marked contrast,

274   some studies [49] simply considered the survival of the affected implants following treatment to

275   represent success. Other studies [28, 29, 53, 57] have considered no further bone loss and presence of PPD

276   ≤ 5mm, with no BOP, to be a successful treatment. Inter- and intra-examiner bias may also lead to

277   variable in outcome measures, for example, force of probing [59]. Furthermore, PPD alone is

278   considered as an invalid marker for the progression of the disease as the reduction in PPD post-

279   treatment may simply reflect gingival recession and/or the surgical technique e.g. apically-

280   repositioned flap procedures [52, 60]. Although radiographic assessment is the only truly non-invasive

281   method for measuring marginal bone levels [52] it can only indicate 'defect-fill' but not the actual re-

282   osseointegration [44] and represents the mesial and distal bone levels only [61]. More recently, cone-

283   beam CT has been used to detect the levels of buccal and lingual bones, although concerns have

284   been raised regarding both radiation exposure and their validity due to a radiolucent halo that may

285   occur around the implant [51].

286   The rationale behind the use of adjunctive systemic antibiotics in the management of peri-

287   implantitis was considered in three studies [40, 49, 58]. There is a lack of evidence to support the

288   prescription of antibiotics in peri-implantitis treatment, which appears operator-dependent. An RCT

289   investigating the effectiveness on systemic antibiotics failed to demonstrate any effect on local

290   microbiological parameters within the defect [53].

291   The most popular surface decontaminant was CHX, which has been tested extensively and

292   approved to have a broad-spectrum anti-bacterial activity [62]. Variation occurred in the CHX

293   concentrations used in two studies (0.12% CHX Vs placebo[29] or 2% CHX Vs 0.12% [28]). Although both

294   studies reported reduced microbial loads when compared to control groups, this did not translate

295   into demonstrable clinical effects on peri-implantitis. Although other chemical antimicrobial

296   treatments were employed e.g. H_2O_2, H_3PO_4, and EDTA, no studies compared their effects to other

297   adjunctive treatments (or placebo-treated control groups). A 4-year review revealed that curette

298   and saline mechanical debridement showed better results than those treated with Er:YAG laser [32],

299   although one study indicates that the Er:YAG laser gave better outcomes at 2-year follow-up [63].

300   Meta-analysis failed to detect any significant difference in the use of surface decontamination (via

301   CHX or Laser) on PPD and RBL. Previous studies have indicated that treatment results are

302   independent of decontamination method and that other risk factors such as oral hygiene, defect

303   configuration are better predictors of treatment success [33, 55].

304   Implantoplasty reduces the macro-surface texture (threads) of the implants. The authors

305   feel that the procedure is effective, partly as it is associated with complete elimination of the

306   primary aetiological factor in peri-implantitis- namely the biofilm. Barbour et al. (2007) reports that

307   it may increase the micro-surface roughness leading to biofilm retention. Furthermore, it may alter

308   implant strength [37, 64] and increase the temperature of the implants surface [65], leading to adverse

309   effects on bone cellularity [66]. The significant improvement of clinical and radiographic parameters

310   following implantoplasty was only based on one study [50, 51] and further research regarding this

311   method is needed.

312   Bone augmentation is limited due to the biological principle of bone regeneration which

313   needs a blood supply to provide nutrition, inflammatory cells to induce bone formation

314   (osseoinduction), and collagen matrix for osseoconduction [43]. The significant effect of bone

315   augmentation on RBL relates to the bone grafts material occluding the defect; no effect on clinical

316   outcome (PPD) is evident [52]. Autogenous bone particles ± membranes in multi-walled defects

317   resulted in significant improvement in PPD and RBL at 36 months [40]. In contrast, Aghazadeh et al.

318   (2012) demonstrated that bovine-derived xenograft (BDX) was more effective than autogenous

319   particulate bone [58]. Khoury and Buchmann (2001) and Roos-Jansåker et al. (2014) were unable to

320   demonstrate any additional benefits in comparison to defects treated with graft material alone [40,44].

321   There are several limitations of this current study due to the inclusion of English language

322   papers only, as well as considerable variability between the different studies included in this review

323   relating to the inclusion/ exclusion criteria. Furthermore, there were only a small number of studies

324   included for each type of surgical intervention, with most studies consisting of relatively small

325   sample sizes and high risk of selection bias in patient inclusion. The high degree of heterogeneity

326   between studies prevents quantitative comparison between the groups [47]. Therefore, neither the

327   differences between the groups nor the overall results were calculated. Furthermore, the meta-

328   analyses should be interpreted cautiously because of the small number of the included studies in

329   each group and the high degree of heterogeneity between them.

330   This current review concludes that a need exists for a long-term, double blind RCT with large

331   sample size and split-mouth technique are required to eliminate patient-related bias. In addition, all

332   potential confounders should be taken into account. Finally, it would be helpful if the definition,

333   diagnosis and the outcomes of the disease were standardised, to be able to conduct more precise

334   reviews, meta-analyses and the evidence-based surgical treatment of these patients.

335

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337

338   **Conclusion**

339   This systematic review shows that a surgical approach to mechanical debridement alone may result

340   in improved clinical outcomes, with no evidence to show the benefits of apically-repositioned flap

341   procedures. No additional clinical benefits were found from the use of surface decontaminants

342   (chemicals or lasers) or additional systemic antibiotics. A single study demonstrated a significant

343   improvement following implantoplasty. Bone augmentation improved radiographic bone levels; the

344   use of additional membrane/s, however, did not result in any additional benefit. The high degree of

345   heterogeneity and the small number of controlled studies make it difficult to identify which

346   procedure is superior to any other.

347

348   **Funding**

349   None

350

351   **Conflict of Interest**

352   The authors confirm that there are no conflicts of interest to declare.

353

354   **Ethical approval**

355   None required

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512

513 **Table 1** Keywords used for the electronic search

Dental Implantology	Peri-implant disease	Procedure	Technique
Tooth Implantation	Periimplantitis	Management	Surgery
Dental Implants	Peri-implantitis	Treatment	Surgical
Tooth implants	Peri-implant disease	Therapy	Surgical approach
Oral Implants	Peri-implant defect		Open flap
Endosseous implants	Peri-implant infection		Access flap
Osseointegrated implants	Peri-implant inflammation		Resective
	Peri-implant bone loss		Regenerative
			Bone regeneration
			Bone augmentation

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Figure legends:

Figure 1 Publishing rate of papers on (a) peri-implant disease and (b) peri-implantitis treatment in

the period 2001-2015.

Figure 2 PRISMA flow chart for study selection.

Figure 3 Proportion of (a) surgical intervention investigated and (b) surface decontamination

methods used in the included studies.

Figure 4 The relationship between observed outcomes and time for (a) BOP and (b) PPD [28, 29, 49].

Figure 5 Forest plot for (a) probing pocket depth (PPD) reductions and (b) radiographic bone level
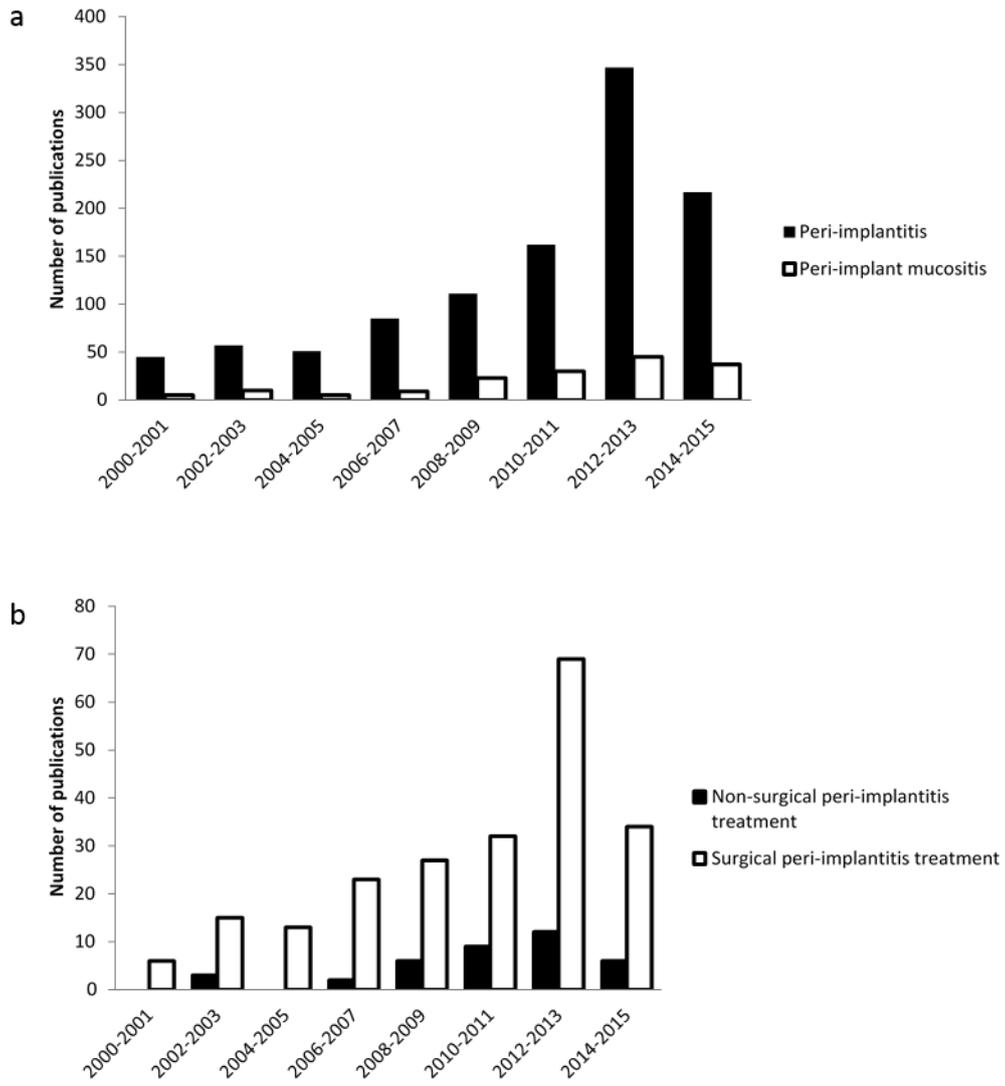
(RBL) changes.

537   Figure 1:
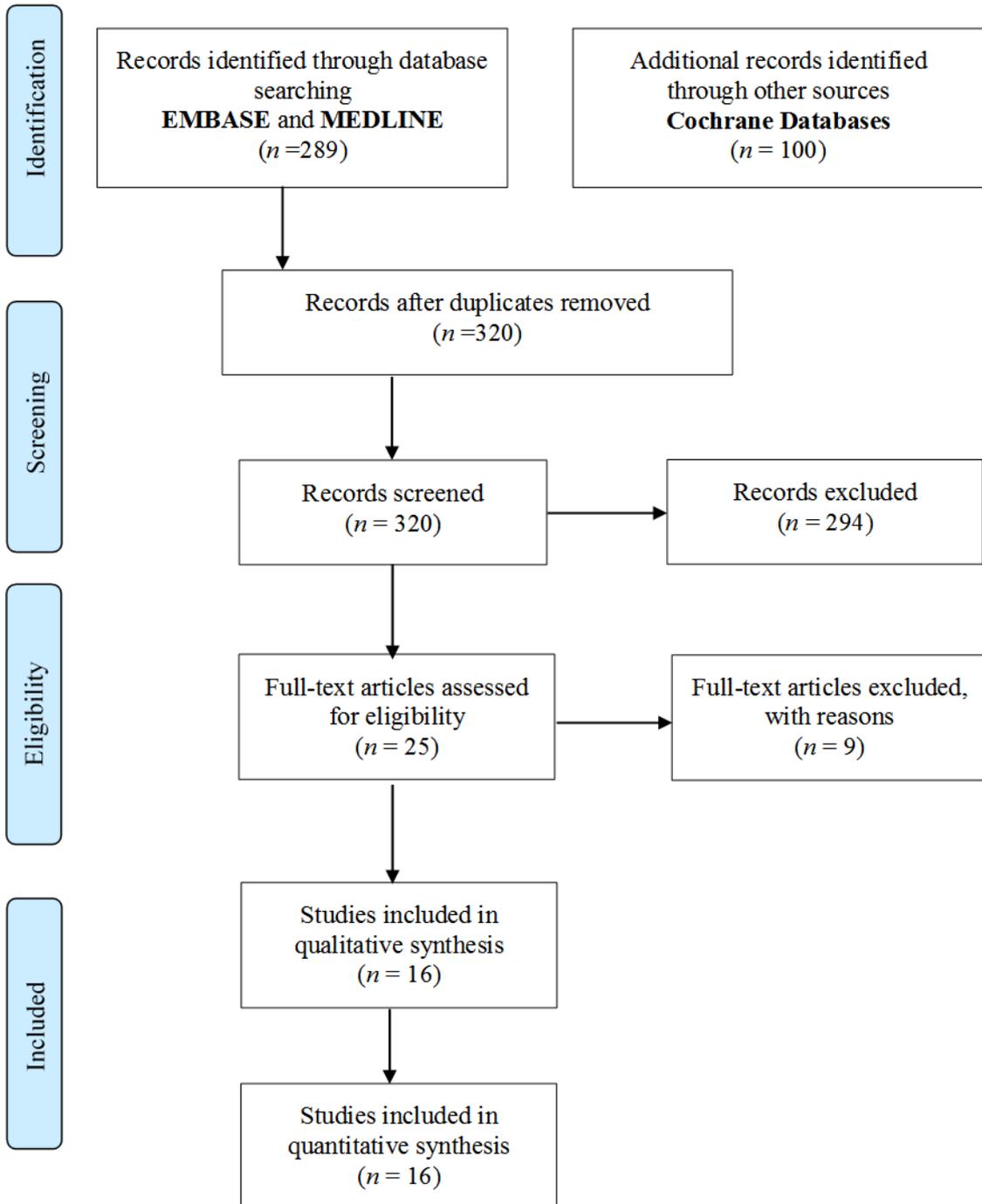
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544   Figure 2:

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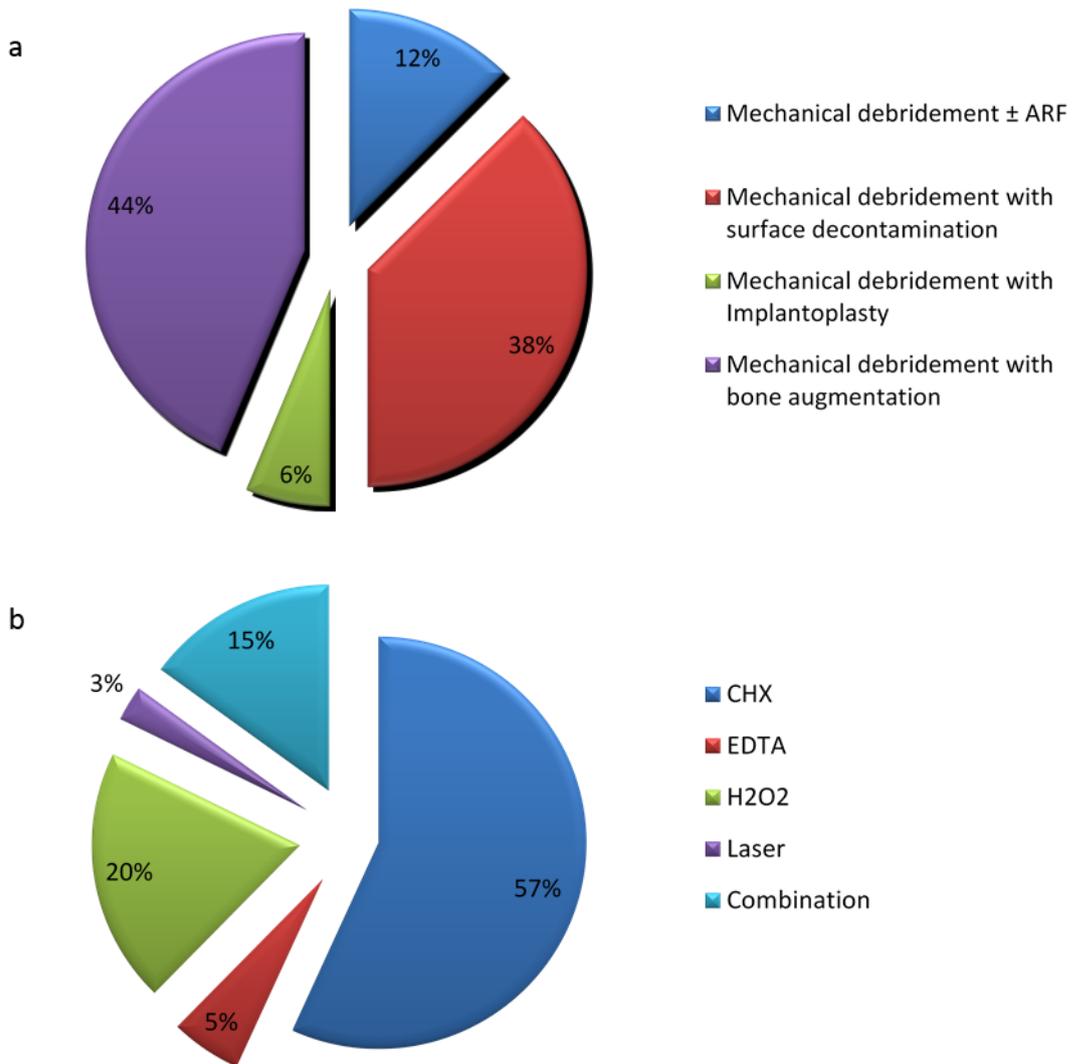

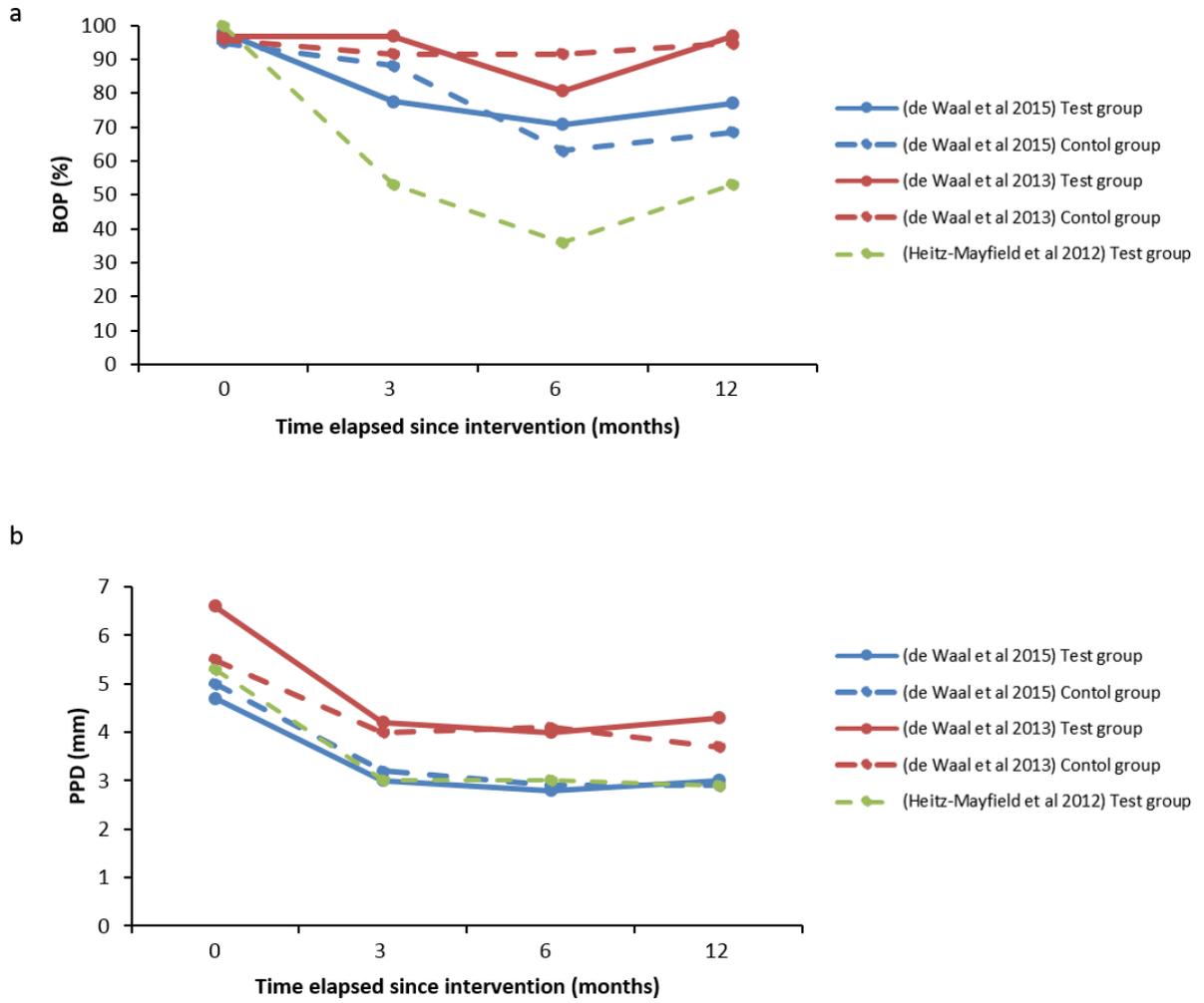
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548 Figure 3:

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555   Figure 4:

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Figure 5:

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Meta-Analysis: PPD

Author	SMD (95% CI)	% Weight
Surface Decontamination		
Bombeccari et al., 2013	-1.64 (-2.36, -0.91)	19.82
de Waal et al., 2013	-1.45 (-1.96, -0.95)	20.30
Schwartz et al., 2013	-0.05 (-1.02, 0.91)	19.11
de Waal et al., 2015	2.28 (1.79, 2.77)	20.33
Carcuac et al., 2016	-0.24 (-0.67, 0.19)	20.44
Subtotal (I-squared = 97.1%, p = 0.000)	-0.21 (-1.70, 1.27)	100.00
.		
Implantoplasty		
Romeo et al., 2005, 2007	-3.33 (-4.37, -2.28)	100.00
Subtotal (I-squared = .%, p = .)	-3.33 (-4.37, -2.28)	100.00
.		
Bone Augmentation		
Wohlfahrt et al., 2012	0.15 (-0.55, 0.84)	100.00
Subtotal (I-squared = .%, p = .)	0.15 (-0.55, 0.84)	100.00
.		
Additional membrane		
Khoury and Bechmann, 2001a	-0.10 (-0.82, 0.61)	34.12
Khoury and Bechmann, 2001b	1.09 (0.16, 2.02)	25.81
Roos-Jansaker et al., 2015	0.14 (-0.46, 0.73)	40.07
Subtotal (I-squared = 52.1%, p = 0.124)	0.30 (-0.31, 0.91)	100.00

NOTE: Weights are from random effects analysis

-5 -4 -3 -2 -1 0 1 2 3
Standarised Mean Difference

b

Meta-Analysis: RBL

Author	SMD (95% CI)	% Weight
Surface Decontamination		
de Waal et al., 2013	0.85 (0.37, 1.32)	32.66
de Waal et al., 2015	0.97 (0.57, 1.37)	33.91
Carcuac et al., 2016	-0.20 (-0.63, 0.23)	33.44
Subtotal (I-squared = 88.6%, p = 0.000)	0.54 (-0.20, 1.28)	100.00
.		
Implantoplasty		
Romeo et al., 2005, 2007	-3.38 (-4.43, -2.33)	100.00
Subtotal (I-squared = .%, p = .)	-3.38 (-4.43, -2.33)	100.00
.		
Bone Augmentation		
Wohlfahrt et al., 2012	-1.05 (-1.80, -0.31)	100.00
Subtotal (I-squared = .%, p = .)	-1.05 (-1.80, -0.31)	100.00
.		
Additional membrane		
Khoury and Bechmann, 2001a	-0.14 (-0.85, 0.58)	31.91
Khoury and Bechmann, 2001b	0.17 (-0.69, 1.04)	21.85
Roos-Jansaker et al., 2015	-0.33 (-0.93, 0.26)	46.24
Subtotal (I-squared = 0.0%, p = 0.640)	-0.16 (-0.56, 0.24)	100.00

NOTE Weights are from random effects analysis

-5 -4 -3 -2 -1 0 1 2
Standarised Mean Difference