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Management of peri-implant mucositis and peri-implantitis

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ABSTRACT

Peri-implant diseases are defined as inflammatory lesions of the surrounding peri-implant tissues, and they include peri-implant mucositis (inflammatory lesion limited to the surrounding mucosa of an implant) and peri-implantitis (inflammatory lesion of the mucosa, affecting the supporting bone with resulting loss of osseointegration). This review aims to describe the different approaches to manage both entities and to critically evaluate the available evidence on their efficacy.

Therapy of peri-implant mucositis and non-surgical therapy of peri-implantitis usually involve the mechanical debridement of the implant surface by means of curettes, ultrasonic devices, air-abrasive devices or lasers, with or without the adjunctive use of local antibiotics or antiseptics. The efficacy of these therapies has been demonstrated for mucositis. Controlled clinical trials show an improvement in clinical parameters, especially in bleeding on probing. For peri-implantitis, the results are limited, especially in terms of probing pocket depth reduction.

Surgical therapy of peri-implantitis is indicated when non-surgical therapy fails to control the inflammatory changes. The selection of the surgical technique should be based on the characteristics of the peri-implant lesion. In presence of deep circumferential and intrabony defects surgical interventions should be aimed for thorough debridement, implant surface decontamination and defect reconstruction. In presence of defects without clear bony walls or with a predominant suprabony component, the aim of the surgical intervention should be the thorough debridement and the repositioning of the marginal mucosa that enables the patient for effective oral hygiene practices, although this aim may compromise the aesthetic result of the implant supported restoration.

Introduction

The use of dental implants for supporting prosthetic rehabilitations has shown highly satisfactory results for the restoration of the patient's function and aesthetics, as well as in terms of long-term survival (2). Dental implants, however, can lose supportive bone, even in cases of successful osseointegration. The main cause for this loss of crestal bone surrounding an implant is local inflammation during the course of peri-implant diseases. These diseases are defined as inflammatory lesions of the surrounding peri-implant tissues and include two different entities: peri-implant mucositis and peri-implantitis (7). Peri-implant mucositis is defined as an inflammatory lesion limited to the surrounding mucosa of an implant, while peri-implantitis is an inflammatory lesion of the mucosa, which affects the supporting bone with loss of osseointegration (19).

Both peri-implant diseases are infectious in nature and caused by bacteria from dental biofilms (18). A recent review concluded that microbiota associated to peri-implant diseases is a mixed anaerobic infection, with a similar composition to that of the subgingival microbiota of chronic periodontitis; although some cases may be specifically associated to other bacterial species, such as *Peptostreptococcus* spp. or *Staphylococcus* spp. (22). Although bacterial pathogens represent the initial step of the disease process, the ensuing local inflammatory response and the misbalance in the host-parasite interaction seems key in the pathogenesis of the tissue destruction defining these diseases. Different risk indicators have been identified, which may intervene in the pathogenesis favouring tissue destruction, such as: poor oral hygiene, a history of periodontitis and cigarette smoking. Less evidence has been demonstrated for the role of diabetes and alcohol consumption (13). The possible role of other factors, such as genetic traits, the implant surface or the lack of keratinised mucosa, are also under validation (63).

Different methods have been used to assess peri-implant tissue health and to diagnose these disease entities. They include peri-implant probing, analyses of peri-implant crevicular fluid or saliva, evaluation of the peri-implant microbiota and radiographic evaluation of the peri-implant bone levels. The consensus today indicates that changes in probing depth (PPD), presence of bleeding on probing (BOP) and suppuration must be evaluated to assess the

peri-implant tissues, while radiographs should be used to confirm peri-implant bone loss (13, 57).

Peri-implant diseases are important disease entities due to their high prevalence and the lack of a standard mode of therapy (7, 35). Although the current epidemiological data are limited, peri-implant mucositis has been reported to affect 80% of the subjects using dental implants and 50% of the implants, while peri-implantitis affects between 28-56% of the subjects and between 12-43% of the implants.

This reviews aims to describe the different approaches to treat peri-implant diseases and to critically evaluate the available evidence to support the different proposed therapies. With this purpose we shall use a recently published systematic review from our research group where only controlled studies were considered (11). In addition, relevant recently published studies were included.

Case definitions for peri-implant diseases

Table 1 depicts the different diagnostic criteria used to define peri-implant mucositis. Although the definitions are heterogeneous, all the selected studies, but one (28) have included BOP of the peri-implant mucosa.

Peri-implant disease definition also varied across studies (see Table 2), but normally included presence of BOP, deep PPD (Figure 1) and bone loss, although using different threshold values (Figure 2). These values for PPD were always deeper than 3 mm and ranged from 1.8 to 3 mm for bone loss. Only one study had exclusively a bone loss criterion (>50%) (5).

Treatment approaches for peri-implant diseases

The evaluation of the different therapies is based on a recently published systemic review of controlled studies with the addition of recently published trials (11). The evaluation has

been divided in three parts: therapy of peri-implant mucositis, non-surgical therapy of peri-implantitis and surgical therapy of peri-implantitis.

Peri-implant mucositis therapy

The treatment of peri-implant mucositis usually includes **mechanical debridement** of biofilm and calculus. This therapy may be rendered either through a professional intervention or by the patient through the home-use oral-hygiene techniques. In addition, **adjunctive antimicrobials**, such as antiseptics, local or systemic antibiotics, may be used in conjunction with mechanical debridement alone or with mechanical debridement and mechanical plaque control protocols. With all these interventions, it is necessary to highlight the importance on the role of the subject's own infection control through the proper motivation and oral hygiene practices in order to prevent the reformation of peri-implant biofilm and calculus around the implant.

Peri-implant mucositis therapy: professional interventions

Mechanical debridement alone involves the supra- and subgingival debridement of the implant surface, the implant neck and the abutment. The main objective is to remove peri-implant biofilm and calculus without altering the implant surface with the goal of reestablishing a healthy peri-implant mucosa (12, 14).

Different debridement systems have been evaluated, normally in combination with polishing the implant surface and/or the prosthetic components with a rubber cup and a polishing paste or with an abrasive sodium-carbonate air-powder system.

a) Currettes of different materials to be used specifically to debride implant surfaces:

- Steel currettes have an external hardness higher than titanium, thus, they are not indicated for cleaning titanium implants. Nevertheless, they can be used in other implant surfaces, such as titanium zirconoxide or titanium oxinitride (45).
- Titanium-coated currettes have a similar hardness to the titanium surface and thus

do not scratch its surface (12) (Figure 3).

- Carbon fiber-curettes are softer than the implant surface and therefore remove bacterial deposits without damaging the surface, although they easily break (14) (Figures 3 and 4).
- Teflon curettes have similar properties to carbon fiber curettes and they have been proposed for its use in combination with air-abrasive systems (21) (Figure 6).
- Plastic curettes are even more fragile and have limited debriding capacity (28) (Figure 5).

b) Ultrasonic devices with polyether-etherketone-coated tips (Figure 7). This is a modified tip, made of a high-tech plastic material, with a stain-steel core. It easily debrides the implant surface and it is comfortable for the patient. The purpose is to debride plaque and calculus from all around the implant neck and the abutment, leaving a clean and a smooth surface (62).

Adjunctive use of antimicrobials, included chlorhexidine-based (CHX) product, have been used as adjuncts to mechanical debridement to prevent bacterial recolonization after the mechanical treatment and to support the patient's oral hygiene practices.

Different CHX formulation and dosages have been evaluated:

- 20 ml of 0.12% CHX mouth rinse, once per day, for 3 months, after professional prophylaxis (10).
- Powered subgingival irrigation with 100 ml of 0.06% CHX, once daily, for 3 months, after professional prophylaxis (10).
- Brushing with 1 cm of 0.5% CHX gel around the implants (see Figure 8), twice daily for 4 weeks (14).
- Rinsing with 10 ml of 0.12% CHX plus brushing with 0.12% CHX gel, twice daily, for 10 days after treatment (28).
- Full-mouth disinfection protocol, after debridement with an ultrasonic device, including: 0.1% CHX gel applied subgingivally; brushing the dorsum of the tongue for 1 min with a 1% CHX gel; spraying each tonsil four times with 0.2% CHX spray; and

rinsing with 0.2% CHX, twice, for 1 min. During the following 14 days, patients were instructed to rinse once daily for 30 s with 0.2% CHX and to spray the tonsils once daily with 0.2% CHX spray (62).

Locally delivered antimicrobials have been used to increase the antibacterial effect of the mechanical debridement and to prevent bacterial colonization of the implant surface. Locally delivered tetracycline was applied in monolithic ethylene vinyl acetate fibers containing 25% w/v tetracycline hydrochloride. The following protocol was performed: fibers were placed around implants in several circular layers until the peri-implant space was completely filled by the fiber; once placement of the delivery system was completed, an isobutyl cyanoacrylate adhesive was applied at the mucosal margin to secure the fiber, and in case of fiber loss prior to 7 days following the fiber placement, another fiber was placed; ten days after initial placement, the fibers were removed (45).

Systemic antimicrobials have been administered adjunctively to mechanical debridement in order to achieve effective antimicrobial levels in the peri-implant crevicular fluid and therefore, support the antibacterial mechanical effect. Different antibiotics, such as azithromycin at a dose of 500 mg per day, during four days have been utilized (12).

Peri-implant mucositis therapy: home-use oral hygiene interventions

Mechanical plaque control may involve the use of manual or powered toothbrushes as well as interproximal aids. Its importance should be highlighted; since long-term success of dental implants will depend on an effective peri-implant supportive therapy where plaque control around implants is key for both the primary prevention of peri-implant mucositis and its secondary prevention once treated. These recommendations are usually found in protocols of primary and secondary prevention of peri-implant mucositis:

- Manual squish grip brush, to be used twice daily for 30 seconds during a period of 6 weeks after a professional removal of plaque from the implant abutments (60).
- Soft manual toothbrush and dental floss, or specialized implant dental floss stocked by the various research sites and end-tuft brushes or interproximal brushes. This protocol of supportive therapy was used twice daily for a period of 6 years (65).
- Powered toothbrush, to be used twice daily for 30 seconds during a period of 6

weeks after a professional removal of plaque from the implant abutments. It gives a three-dimensional brushing action, coupling a sonic frequency and a high-speed oscillation that provides a deeper dental and peri-implant cleaning (60).

- Counter-rotational powered brush. It has 10 spaced tufts of bristles that rotate 1.5 turns before reversing for another 1.5 turns. This reverse movement is intended to increase the scrubbing action and to force bristles into interproximal and subgingival areas. Adjacent tufts counter-rotate relative to each other, which has a stabilizing effect when the brush is placed on a given site. The bristle configuration is designed to reach between teeth and subgingivally. This design is different from other leading powered brushes, which use oscillating, vibrating or acoustic modes of action. This protocol of maintenance was used twice daily for a period of 6 years (65).

Chemical plaque control may provide additional benefits as adjuncts to tooth brushes (manual or powered) and interdental-cleaning devices. In the 6th European Workshop in Periodontology, it was concluded that there was a need to determine whether antimicrobials used in periodontal therapy are also effective in the treatment of peri-implant diseases and to what extent initial improvements are sustained over long term (19). Therefore, different chemical products in combination with mechanical oral hygiene techniques have been studied. Some of these adjunctive protocols are listed:

- Triclosan/copolymer toothpaste. A 0.3% triclosan and 2.0% PVM/MA copolymer in a sodium fluoride silica base toothpaste, in conjunction with a soft bristle brush, for 6 months twice daily during 60 seconds each (29, 58).
- Fluoride toothpaste. A toothpaste containing 0.243 sodium fluoride silica-based tooth paste, in conjunction with a soft bristle brush, for 6 months twice daily during 60 seconds each (29, 58).
- Essential oils rinse. After a dental prophylaxis, Listerine® was used after a standard oral hygiene procedure, twice daily during 30 seconds for a period of 3 months (6).
- CHX rinse. Rinsing twice a day with a 0.12% CHX, in conjunction with a soft manual toothbrush and dental floss, specialized implant dental floss and end-tuft brushes or interproximal brushes. This protocol of supportive therapy was used for a period of 6 years and CHX rinsing was combined with the use of a counter-rotational powered brush (65).

Peri-implant mucositis therapy: evaluation in controlled trials

At least seven randomized controlled clinical trials (RCTs) evaluating the therapy of peri-implant mucositis have been published (6, 10, 14, 28, 29, 45, 62). In these studies, the sample size ranged between 8-59 patients and the mean follow-up varied from 3 to 8 months. Three studies included patients with treated periodontitis (14, 29, 62); two included periodontally healthy subjects (10, 28); and two did not report the periodontal status (6, 45).

Studies can be grouped in two categories depending on whether the intervention was professional or based on the patient's oral hygiene practices:

- Professional mechanical debridement with or without the adjunctive use of antimicrobials (14, 28, 45, 62).
- Home-use oral hygiene intervention. After an initial prophylaxis, patients were instructed to use an antiseptic as adjunct to conventional oral hygiene techniques during a certain period of time (3-6months) (6, 10, 29).

Treatment efficacy is based on the evaluation of the changes in the gingival inflammatory parameters. BOP was considered the main clinical outcome variable, although PPD and plaque index (PI) were usually reported too. Microbiological outcomes were reported in two articles (14, 62). Only one study reported the number and percentage of cases of mucositis solved (complete resolution of BOP at all the measured sites) (14).

Based on these clinical outcomes:

- When mechanical debridement alone was compared to mechanical debridement plus the adjunctive use of different protocols of CHX (14, 28, 62) or locally delivered tetracycline (45) the reductions of BOP were significant in both groups, without a clear benefit derived from the use of CHX or locally delivered tetracycline. The results for PPD showed higher variability as compared to BOP. While two studies found a similar PPD reduction in both groups (14, 62), one found higher reductions in the control group (28) and another did not find any change in PPD in the test or in the control groups (45). Plaque index (PI) was not evaluated in one paper (14) and the results for the other trials showed either a similar PI reduction in both groups (28, 62) or no changes in any of the

groups (45). For microbiological outcomes, no differences could be seen between groups when using PCR (62) or DNA probes (14).

- When evaluating home-use oral hygiene interventions, different plaque control regimens have been compared. Two studies have evaluated the adjunctive home use of antiseptics after an initial prophylaxis (6, 10) and one study has evaluated the home use of two different toothpastes as unique treatment of peri-implant mucositis (29). The reported results are: a) a higher reduction of BOP and PI after 3-months using an essential oils mouth rinse compared to the negative control, but no differences for PPD or CAL (6); b) a greater reduction in PI, in the modified bleeding index and in the stain index, when comparing irrigation with 0.06% CHX using a powered oral irrigator with a special subgingival irrigating tip to rinse with 0.12% CHX mouth-rinse once daily during 3 months (10); c) a higher performance of triclosan/copolymer containing toothpaste, when compared with a sodium fluoride toothpaste after a period of home-use of 6 months in terms of BOP, despite no changes were noted among groups for PI or PPD (29).

Peri-implant mucositis therapy: summary and conclusions

Peri-implant mucositis treatment usually includes mechanical debridement of biofilm and calculus either by a professional intervention or by home-use oral-hygiene techniques with or without the adjunctive use of antimicrobials.

Professional mechanical interventions with or without the adjunctive use of antimicrobials have been shown to significantly reduce peri-implant tissue inflammation (as evaluated by reductions in BOP) and therefore, peri-implant mucositis seems to be successfully treated by professional mechanical debridement independently of the adjunctive use of an antimicrobial.

In the case of home-use oral hygiene products, mechanical plaque control together with the use of an antiseptic may benefit the treatment of peri-implant mucositis in terms of BOP reduction and, sometimes, in PI reduction.

In summary, clinical trials evaluating the treatment of peri-implant mucositis provide a variety of effective protocols in reducing peri-implant tissue inflammation and therefore, the clinician should select those that adapt better to the specific patient's circumstances.

Peri-implantitis non-surgical therapy

The basis for peri-implantitis therapy is infection control through the debridement of the implant surface with the aim of debriding the adhered biofilm and to reduce the bacterial load below the threshold level for disease (64). Mechanical debridement around dental implants presents some specific characteristics: the absence of periodontal ligament, a variable (more/less rough) implant surface and different types of abutment connection. All these factors can jeopardize not only the professional therapy, but also patient's self-performed hygiene, since these characteristics may facilitate biofilm formation when the surfaces get exposed to the oral environment (34). In order to overcome these limitations, different protocols combining adjunctive treatments have been proposed:

Peri-implantitis non-surgical therapy: mechanical or automatic debridement

Similar objectives and technologies for the mechanical debridement of implant surfaces (curettes, air-abrasive devices, ultrasonic devices, lasers) have been evaluated for the treatment of peri-implantitis, with the main difference that they are aimed more subgingivally to decontaminate the exposed implant surfaces.

In regards to the use of **curettes** for scaling implant surfaces, the same considerations described for the treatment of peri-implant mucositis are valid for the non-surgical treatment of peri-implantitis. Different types of curettes have been studied, mainly those made of carbon fibre (15) or titanium (25, 37, 44) and most of the protocols included an adjunctive polishing with rubber cup and polishing paste.

Standard **powdered air abrasive systems** are based on the air-spray of sodium bicarbonate. They are used for polishing and removing tooth stains, but cannot be used for implant instrumentation since they may cause hard and soft tissue damage due to their high abrasiveness (17). Recently, a powered air abrasive system based on a low abrasive amino-

acid glycine powder (Figure 9) has demonstrated to effectively remove biofilm from the root surface, without damaging hard and soft tissues (27) and it has been recommended for debriding implant surfaces. It uses a specially designed nozzle, consisting of a thin flexible plastic tube (length: 1.7 cm; diameter: 0.8 mm at the tip) that is fitted with three orthogonally orientated holes. This specific design is associated with a horizontal exit of the air powder mixture and a reduced pressure, thus preventing emphysema formation in the adjacent tissue. The hand piece (Air- Flows EL-308/A, EMS) should be guided in a circular motion from coronal to apical parallel to the implant surface in a noncontact mode and the instrumentation time at each aspect (i.e. mesial, distal, vestibular and oral) should be limited to 5 seconds, as recommended by the manufacturer (42). It has also been described to place the nozzle in the pocket mesially, lingually, distally and buccally, approximately for 15 s in each position. Circumferences should be done around the implant, attempting to cover the entire exposed implant surface (33, 44).

Similar to curettes and air abrasive devices, **ultrasonic devices** in the treatment of peri-implantitis are aimed to effectively remove biofilm and calculus without altering the implant surface. To accomplish this, different tip modifications have been proposed, such as carbon fiber, silicone or plastic (15, 25, 37). Another modification to the conventional ultrasonic device is the *Vector® system* (Dürr Dental, Bietigheim-Bissingen, Germany), where the horizontal vibration is converted by a resonating ring into a vertical vibration, resulting in a parallel movement of the working tip to the surface.

The use of **lasers** has been proposed in the treatment of peri-implantitis due to its anti-infective, physical and ablation properties. The Er:YAG laser technology (Figure 10) is the one that has shown the highest potential for use in the treatment of peri-implantitis, due to its efficacy to remove subgingival plaque and calculus without significantly damaging the implant surface (59). This laser is used for peri-implantitis treatment with a special hand-piece containing a cone-shaped sapphire tip, which should be used in a parallel and semicircular motion around the circumference of the pocket. The laser should be set with an energy of 100 mJ and a frequency of 10 Hz (24, 33, 50, 56). Recently a protocol combining a diode laser with a wavelength of 660 nm and a power density of 100 mW during 10 seconds

in each pocket the use of the dye phenothiazine chloride for 3 minutes followed by irrigation with 3% hydrogen peroxide has been proposed (44)

All the debridement systems described above can be combined to obtain a better removal of biofilm and calculus: the combination of sodium carbonate air-powder and resin cures has been evaluated (9).

Peri-implantitis non-surgical therapy: adjunctive use of antimicrobial products

Adjunctive therapies such as antibiotics and antiseptics have been proposed to improve the results of non-surgical debridement since the reduction of the bacterial loads to levels compatible with tissue health is difficult to accomplish with mechanical means alone (36).

Chlorhexidine-based products as gels, irrigation and/or rinses in different formulations and regimes have been reported, such as: a) repeated irrigation of the peri-implant pocket with CHX 0.2% in one session (4); b) single application of CHX gel 1% with a disposable syringe (30, 32); c) repeated application of CHX gel 1% at treatment and 30 and 90 days after (31); d) combination of pocket irrigation with CHX 0.2% plus CHX gel 0.2% applied subgingivally in each implant at the day of intervention and CHX mouth rinse 0.2% twice daily for two weeks (50, 56); e) and pocket irrigation with CHX 0.12% plus CHX gel 1% (42).

Different protocols have been evaluated using **locally or systemically delivered antimicrobials**: a) single-unit dose of 1 mg minocycline and 3 mg poly-glycolide-co-dl-lactide placed submucosally per treatment site, at treatment time and 30 and 90 days after (31); b) a unique dose of 1 mg minocycline microspheres (30, 44); c) minocycline microspheres at treatment time and 180 and 270 days after (43); d) or topical irrigation with a solution containing 8.5% by weight of doxycycline and 37% by weight of poly d,l-lactide dissolved in a biocompatible carrier of N -methyl-2-pyrrolidone (4). Systemic antibiotics have been also used, but there are not controlled clinical trials evaluating their effect.

Peri-implantitis non-surgical therapy: evaluation in controlled trials

At least nine controlled trials, reported in thirteen articles, have evaluated the non-surgical therapy of peri-implantitis. Although the same case definition for peri-implantitis was not

used in all studies, all included BOP of the peri-implant mucosa, increased PPD and radiographic bone loss. The sample size ranged between 18-42 patients and the mean follow-up varied between 3 to 12 months.

Different treatment protocols were evaluated that can be grouped in three categories:

- Antimicrobials. Mechanical debridement was performed with the adjunctive use of an antiseptic or a locally delivery antibiotic (4, 30, 31, 42, 44).
- Lasers. Two types of lasers were compared to different protocols of mechanical debridement (24, 33, 44, 50, 56).
- Ultrasonic devices. Vector® system was compared to two different types of curettes (15, 25, 37)

Efficacy was evaluated by means of PPD and BOP reductions as the main outcome measurements. As secondary outcome variables, changes in PI, clinical attachment level (CAL), microbiological outcomes and radiographic bone level changes were used in some studies.

Based on the effect on these clinical outcomes we can draw the following conclusions, with regards to the adjunctive use of **antimicrobials**:

- Three publications reported results of the same study, with variations in the follow-up (3-12 months) and in the type of analysis (patient- or implant-based) (30, 31, 44). They compared the use of carbon-fibre curettes plus CHX gel versus carbon-fibre curettes plus locally delivered minocycline, and reported a very small added effect with the use of minocycline both on PPD (0-0.15 mm in the CHX group, 0.3-0.4 mm in the minocycline group) and BOP (8-38% in the CHX and 16-26% in the minocycline group). Interestingly, authors observed that when repeating the minocycline application in residual pockets, the results were much better (31).
- In the second subgroup, plastic curettes alone were compared to plastic curettes plus the adjunctive use of locally delivered doxycycline (4). After a mean follow-up period of 4.5 months, changes in PPD and BOP were only significant in the antibiotic group. While the control group had a mean reduction in PPD of 0.28 mm and in BOP of 13%, the experimental group experienced a reduction of 1.15 mm and 27%, respectively.

- In the last subgroup, carbon-fibre curettes plus CHX irrigation and gel application was compared to a glycine-based powder air-abrasive (42). After 6 months of follow-up, both groups reduced similarly PPD (0.5 mm in the CHX group and 0.6 mm in the air-abrasive group), although BOP was more reduced in the air-abrasive group (43% versus 11%, respectively).

Based on these results, locally delivered antibiotics may provide an extra clinical benefit when compared to CHX, especially when repeated applications are administered. Nevertheless, data should be analysed carefully, since the clinical effect was limited.

With regards to the evaluation of **lasers**, the following conclusions were reported:

- In the group of lasers, two types of lasers have been studied, Er:YAG and diode lasers, although the vast majority of the research has focused on Er:YAG lasers. In a first group of studies, Er:YAG laser was compared to conventional debridement with plastic curettes and subgingival irrigation with CHX (50, 56). It was reported that up to the 6 months evaluation, the Er:YAG laser obtained higher PPD and BOP reduction than the conventional debridement, but after 12 months both groups experienced a relapse in the clinical benefits previously obtained, although this rebound was higher in the control group. Therefore, it can be stated that Er:YAG laser improved the clinical outcomes but not enough to control peri-implant infection one year after therapy.
- A second group of studies analysed the clinical and microbiological effect of Er:YAG laser compared to glycine-based air-abrasive (24, 33). After a 6 month-period, both groups significantly reduced PPD, without differences between groups (0.9 mm in the air-abrasive group and 0.8 mm in the laser group). Data for BOP values showed that while the laser group had 31% of sites free of bleeding, the air-abrasive group had 25% of sites free of bleeding (33). For the microbiological outcomes, it was found that none of the groups could reduce bacterial counts at 6 months and that *Porphyromonas gingivalis* counts were higher in cases with progressive peri-implantitis (24).
- The diode laser has been used in combination with photodynamic therapy and locally delivery minocycline after initial mechanical debridement with titanium curettes and

glycine-based air-abrasive (44). At the 3-month visit, both groups had significantly reduced PPD and BOP, although no further changes could be seen up to the 6 months follow-up. No differences could be seen between groups for PPD and BOP reduction at any time point. Nevertheless, at the end of the study, the photodynamic group had double of cases with complete resolution of the inflammation (30% versus 15%).

Based on these results, the use of lasers could provide short-term clinical benefits in the non-surgical treatment of peri-implantitis (up to 3 months). Nevertheless, we have to carefully analyse the cost-benefits of this therapy, since the results were similar to the ones obtained with easier and cheaper technologies.

And finally, with regards to the evaluation of **ultrasonic devices**, the following conclusions were taken: the Vector® system was compared to carbon-fibre (15) or titanium (25, 37) curettes after 6 months of follow-up. It was observed that carbon-fibre curettes had a null effect on PPD reduction with an increase in BOP. In the other hand, the Vector® system could not reduce PPD but was able to reduce BOP from 63% to 36% (15). In the case of titanium curettes, authors could not find neither intra- nor inter-group differences for PPD, BOP changes (37) or in microbiological outcomes (25). Therefore, we can conclude that this technology was ineffective in resolving peri-implantitis and had a very small effect in mucosal inflammation.

Peri-implantitis non-surgical therapy: summary and conclusions

Several protocols have been reported for the non-surgical treatment of peri-implantitis. They usually involved the mechanical debridement of the implant surface by means of curettes (4, 15, 25, 30, 31, 37, 42, 44, 50, 56), ultrasonic devices (15, 25, 37), air-abrasive devices (24, 33, 42, 44); or lasers (24, 33, 44, 50, 56), combined or not with some sort of chemical action mainly based on local antibiotics (4, 30, 31, 44) or antiseptics such as CHX (30, 31, 42, 44, 50, 56).

The analyses on the efficacy of these protocols in controlled trials revealed a very limited effect in terms of the surrogate outcome PPD, while the effect on BOP was more significant.

Out of the thirteen selected studies, the largest PPD reduction was 1.2 mm (4) and final BOP scores were almost in all the papers greater than 50%. In addition, this treatment did not provide changes in the bone levels. On the other hand, it is also important to consider important limiting factors in these studies, such as the limited follow up (only 12-month data is currently available), reduced sample sizes and the lack of a defined control group.

Based on the available data, it seems that the non-surgical therapy of peri-implantitis is not effective in disease resolution, since only limited improvements in the main clinical parameters are reported and there is a clear tendency for disease recurrence. It is therefore recommended to consider advanced therapies, such as surgical interventions, when non-surgical peri-implant surgery is unable to significantly improve the clinical parameters.

Peri-implantitis surgical therapy

As described before, non-surgical treatment of peri-implant diseases have shown modest efficacy and one possible explanation for these limited results may be related to a defective decontamination of the implant surface exposed to bacterial biofilms. Indeed, the geometry of the threads and the modification of the implant surface may complicate the cleansibility when bone loss occurs and the exposed implant surfaces are exposed to bacterial biofilms, especially rough surfaces (34). Moreover, the histopathology of the peri-implant lesions is characterized by presence of an inflammatory cell infiltrate extending apically in direct contact with the bone crest and leading to loss of osseointegration (3). In addition, peri-implantitis has been associated to a Gram-negative anaerobic microbiota, similar to severe periodontitis around natural teeth, which might be difficult to control with non-surgical therapy alone (36).

As an additional objective to the treatment of peri-implant infection, the treatment of peri-implantitis should aim for bone regeneration and the attainment of re-osseointegration. This phenomenon of direct bone to implant contact on a previously contaminated implant surface has been documented in pre-clinical models, although never demonstrated in humans (23, 26). It is therefore, the rationale of the surgical treatment of peri-implantitis

two-fold: to improve implant surface cleanability and to modify soft and hard peri-implant tissues anatomy in order to obtain re-osseointegration.

Peri-implantitis surgical therapy: decontamination of implant surface

When the implant surface is exposed to oral biofilms, it becomes contaminated and, in order to promote healing, a decontamination of the surface is mandatory. Numerous approaches have been used for implant surface decontamination during peri-implant surgery, including mechanical, chemical or laser treatments.

Mechanical decontamination

It consists of the physical removal of hard and soft tissue deposits on the contaminated exposed implant surface. Instruments for mechanical debridement usually include curettes, ultrasonic devices with special tips and air-powder abrasive systems. The advantages and limitations of these systems have already been described when used in non-surgical therapy (33).

A second, and more aggressive approach has been proposed, consisting on the smoothing of the implant surface eliminating the rough implant surface resulting in a polished smooth surface more amenable for oral hygiene practices. This procedure termed “implantoplasty” (38) is carried out with burs and stones under copious irrigation, since there is an important rise in temperature extensive local contamination with titanium (61).

Chemical decontamination

The rationale of chemical treatments is to apply substances directly on the implant surface for its disinfection/decontamination. Citric acid, hydrogen peroxide, CHX and/or saline have been utilized all providing similar results in experimental studies (16) (46).

Lasers

Lasers have also been used to decontaminate the implant surface, although scientific literature often failed to find clinical benefits. Schwarz and co-workers noticed that erbium lasers were able to determine significant advantages in terms of bleeding on probing and clinical attachment level, however no differences were noticed when compared to

conventional mechanical treatment (53). No differences between laser and conventional treatment were also noted with a CO₂ laser as adjunct to both resective and reconstructive technique (8).

Peri-implantitis surgical therapy: surgical techniques

Various surgical techniques have been recommended depending on the final objective of the surgical intervention: a) access for cleaning and decontaminating the implant surface (access flaps); b) access for cleaning and decontamination plus exposing the affected surfaces for cleaning (apically repositioned flaps); and c) access for cleaning plus aiming for bone regeneration and re-osseointegration (regenerative techniques)

Access Flap Surgery

The objective of this flap surgical intervention is to conserve and to maintain all the soft tissues around the affected implant and to focus mainly on the decontamination of the implant surface. Usually, intracrevicular incisions (Figure 11a) are made around the affected implants and mucoperiostal flaps are raised both buccally and palatally/lingually (Figure 11b). Degranulation of the peri-implant inflamed tissues is best accomplished with titanium curettes and finally implant surface decontamination is performed with one of the methods previously described. Finally, the flaps are repositioned and adequately sutured (Figure 11c). Since there is no evidence from human or animal studies that implant surface decontamination alone may result in re-osseointegration, this surgical intervention aims to eliminate the inflammatory changes responsible of the disease process. Since this technique aims to maintain the position of the soft tissue margin around the implant neck, this can only be attained when the peri-implant bone loss is shallow.

Apically positioned flaps

This surgical approach has been advocated in order to enhance self-performed oral hygiene and reduce the pockets around affected implants (20). Technically, a reverse beveled incision is designed depending on the probing pocket depth and the width and the thickness of the peri-implant mucosa (Figure 12a). Vertical releasing incisions may be needed in order to apically position the flap. Mucoperiostal flaps are raised both buccally and palatally/lingually (Figure 12b). The collar of affected tissues is then removed and implant

surfaces are thoroughly decontaminated. Often osteoplasty, carefully performed with bone chisels, is needed. Finally, flaps are sutured in order to leave the previously affected part of the implant exposed to the oral cavity (Figure 12c). In order to smoothen the exposed part and to decrease the post-surgical contamination of the implant surface, implantoplasty has been suggested (38). This technique may be indicated for peri-implantitis with suprabony defects or one-wall intrabony defect. It is obviously a technique chosen mainly for non-aesthetical areas (39).

Regenerative surgical techniques

Regenerative approaches have two main objectives:

- to support the tissues dimension during the healing process, avoiding recession of the mucosa.
- to enhance the chance of obtaining re-osseointegration, using reconstructive and regenerative techniques/materials.

In this technique, intracrevicular incisions are often performed in order to maintain the total amount of soft tissues (Figure 13a). After elevation of buccal and lingual periosteal flaps, degranulation of the defect is performed with titanium instruments. After decontamination of the implant surface, a graft is placed around the implant, filling the intrabony component of the defect (Figure 13b). Grafting may be performed with either autologous bone (16) or bone substitutes (52). The graft may be covered (Figure 13c) with a resorbable or non-resorbable membrane (16, 41). Finally, flaps are coronally positioned and sutured in order to determine healing (Figure 13d), either with a non-submerged or a submerged approach (1).

A combined regenerative and resective approach has also been proposed (53), including extensive implantoplasty in the suprabony component of the defect; conversely, for the intrabony component, two procedures of decontamination were compared, namely an Er:YAG laser or plastic curettes and sterile saline. This technique is based on the knowledge that the most common peri-implant defects normally include an intrabony component and a more coronal supra-bony portion. The intrabony component of the defect was treated with a collagen membrane and a bovine xenograft (53) and the supra-bony component with resective surgery.

Peri-implantitis surgical therapy: evaluation in controlled trials

There are a limited number of controlled studies evaluating the surgical therapy of peri-implantitis, and they are small in sample size, limited follow up and high risk of biases (11). Moreover, the evaluation of efficacy is hampered by the lack of a standard mode of therapy, and therefore, there is no clear control therapy. In fact, study designs comparing non-surgical treatment versus open flap debridement or open flap debridement versus apically repositioned flaps are lacking.

Reported studies can be grouped in three categories according to their main objective:

- to compare different methods of implant surface decontamination, while using the same surgical approach such as resective, reconstructive or mixed (8, 38, 51, 53).
- to compare grafting peri-implant bony defects with or without a membrane (16, 41).
- to compare two different types of reconstructive surgery (48, 52).

As discussed in the non-surgical therapy section, clinical conclusions are drawn based on the results from surrogate periodontal outcomes. The validity of these surrogates has been extensively studied in Periodontology but it is not clear whether their utility is similar in implant dentistry. Indeed, few papers have provided information on true end-point outcomes (peri-implantitis resolution) and none in regards to the evaluation of the surgical treatment of peri-implant diseases (14, 33).

In spite of these limitations and based on the results from surrogate outcomes, different conclusions can be drawn:

- When comparing apically repositioned flaps with and without implantoplasty, after 24 months, groups treated with implantoplasty demonstrated significant improvements in regards to PPD and CAL levels (38). Another study (8) compared decontamination with air powder abrasion versus CO₂ laser, used during resective or reconstructive surgery (with a mixture beta-tricalcium phosphate and autologous bone), demonstrating no significant differences between the four groups at the short-term evaluation. However, in longer follow-ups, laser decontamination and soft tissue resection showed the highest performance whereas no differences were noted among air abrasion and laser treatment when reconstructive surgery was

performed. A third study (53) reported no differences in terms of peri-implant bleeding or clinical attachment levels, at 6 months, between decontamination with plastic curettes and saline versus Er:Yag laser, after extensive implantoplasty, and treatment of the intrabony component with bovine xenograft and collagen membrane.

- In reconstructive approaches, an important conclusion was the lack of differences whether or not to use a resorbable membrane. With reconstructive surgery with autogenous bone grafting and decontamination with CHX, citric acid, hydrogen peroxide and saline, after 3 years of follow-up, a significant decrease of PPD was observed in both groups, without intergroup differences (16); with a bone substitute and decontamination with hydrogen peroxide and saline, one-year results showed no bleeding in 75% of implants in both groups, and similar PPD reduction, CAL gain or defect fill (41), with 3-year results confirming the previous finding (40).
- When comparing different approaches of reconstructive surgery, some conclusions based on surrogate parameters were drawn. The comparison of a graft of nanoapatite versus a bovine xenograft, with collagen membranes and decontamination with plastic curettes and CHX as gel and solution, despite initially similar results (48), showed after 4 years that the usage of xenograft and collagen membrane appeared superior in terms of PPD reduction and CAL gain (52).

Peri-implantitis surgical therapy: summary and conclusions

Although the presented evidence is very limited to establish solid conclusions and recommendations, some suggestions can be made based on the available evidence.

The characteristics of the peri-implant bone defects caused by peri-implantitis may help to select the most suitable surgical approach. A classification has been proposed for categorizing the morphology of the peri-implant defects and based on this morphology develop a decision making tree for the recommended surgical intervention (49). In presence of circumferential bony defects with intact bony walls the use of regenerative surgical approaches provided improved outcomes when compared with some degree of buccal dehiscence morphologies (54). Therefore, regenerative surgical techniques should be used in presence of circumferential and intrabony defects. On the other hand, when defects show a

predominant suprabony component, an apical repositioned flap should be recommended in non-aesthetic areas. Finally, even though there is no evidence to support the use of access flaps, they may be suggested for shallow defects or in aesthetic areas after unsuccessful non-surgical treatment.

In terms of surface decontamination (Figures 14a-d), literature is not clearly indicating superiority of a specific decontamination protocol. In fact, the usage of lasers did not show additional advantages over traditional systems (8, 53), and even rinsing with saline has shown successful outcomes (46).

There is no evidence to recommend the use of a specific regenerative surgical technique, being grafting with autogenous or xenogeneic grafts or bone substitutes, although it seems clear that the use of barrier membranes does not provide a clear added value (16, 40, 41).

List of figures

Figure 1: Peri-implant probing pocket depth.

Figure 2: Bone loss around implants: radiograph of implants with horizontal bone loss.

Figure 3: implant biofilm debridement with a titanium curette.

Figure 4: Peri-implant biofilm debridement with a carbon fiber curette.

Figure 5: Peri-implant biofilm debridement with a plastic curette.

Figure 6: Peri-implant biofilm debridement with a Teflon curette (PTFE-e).

Figure 7: Peri-implant biofilm debridement with a polyetheretherketone-coated ultrasonic tip.

Figure 8: Peri-implant oral hygiene procedure with an interdental brush and chlorhexidine gel.

Figure 9: Peri-implant biofilm debridement with a glycine-based air abrasive system.

Figure 10: Peri-implant biofilm debridement debridement with Er:YAG laser.

Figure 11a: Surgical therapy: access flap. Surgical incisions.

Figure 11b: Surgical therapy: access flap. Mucoperiosteal flaps.

Figure 11c: Surgical therapy: access flap. Suturing.

Figure 12a: Surgical therapy: resective surgery. Incisions.

Figure 12b: Surgical therapy: resective surgery. Mucoperiosteal flaps.

Figure 12c: Surgical therapy: resective surgery. Suturing.

Figure 13a: Surgical therapy: regenerative surgery. Incisions.

Figure 13b: Surgical therapy: regenerative surgery. Defect fill with bone substitute.

Figure 13c: Surgical therapy: regenerative surgery. Resorbable membrane to cover the bone defect.

Figure 13d: Surgical therapy: regenerative surgery. Suturing.

Figure 14a: Implant surface decontamination during surgery with hydrogen peroxide.

Figure 14b: Implant surface decontamination during surgery with Er:YAG laser.

Figure 14c: Implant surface decontamination during surgery with glycine-based air abrasive.

Table 1. Diagnostic criteria for peri-implant mucositis.

First author, year	Mucositis definition
Heitz-Mayfield et al. (2011) (14)	BOP & no BL
Thöne-Mühling et al. (2010) (62)	BOP and/or GI ≥ 1 on at least one site & no BL in the previous 2 y
Ramberg et al. (2009) (29)	BOP
Porras et al. (2002) (28)	Plaque & PPD ≤ 5 mm & low inflammation mSBI
Felo et al. (1997) (10)	BOP & mGI >1.5 & mPI >1.5 ; PPD ≤ 3 mm
Ciancio et al. (1995) (6)	BOP & mGI >1.5 & mPI >1.7

BOP, bleeding on probing; BL, bone loss; GI, gingival index; PPD, probing pocket depth; mGI, modified GI; mSBI, modified sulcular bleeding index; mPI, modified plaque index.

Table 2. Diagnostic criteria for peri-implantitis.

First author, year	Peri-implant disease definition
Schar et al. (2012) (44)	PPD: 4-6mm & BOP at ≥ 1 site & RBL: 0.5-2mm
Renvert et al. (2011) (33)	PPD ≥ 5 mm & BOP/SUP & RBL > 3 mm
Renvert et al (2009) (37), Persson et al. (2010) (25)	PPD ≥ 4 mm & BOP/SUP & RBL < 2.5 mm
Renvert et al. (2008) (31)	PPD ≥ 4 mm & BOP/SUP & BL < 1.8 mm (3 threads) & presence of <i>Pg, Pi, Pn, Tf, Aa, Td</i>
Renvert et al. (2004, 2006) (30, 32)	PPD ≥ 4 mm & BOP/SUP & BL < 3 threads & presence of <i>Pg, Pi, Pn, Tf, Aa, Td</i>
Schwarz et al. (2005, 2006) (47, 56)	Moderate (PPD > 4 mm) to advanced (PPD > 7 mm) BL & BOP/Sup & PI < 1 & keratinized mucosa
Karring et al. (2005) (15)	PPD ≥ 5 mm & BOP & RBL=1.5mm & exposed implant threads
Aghazadeh et al. (2012) (1)	PPD ≥ 5 mm & BOP/SUP & RBL ≥ 2 mm & Angular peri-implant bone defects ≥ 3 mm
Schwarz et al. (2011) (53)	PPD > 6 mm & RBL > 3 mm
Roos-Jansåker et al. (2007) (41)	BOP/SUP & BL > 3 threads
Deppe et al. (2007) (8)	PPD > 4 mm or BOP, vertical BL
Schwarz et al. (2006, 2008, 2009) (48, 52, 55)	PPD > 6 mm & RBL > 3 mm
Romeo et al. (2005, 2007) (38, 39)	PPD > 4 mm & BOP/SUP & peri-implant radiolucency
Khoury & Buchmann (2001) (16)	RBL $> 50\%$

BOP, bleeding on probing; SUP, suppuration; BL, bone loss; RBL; radiographic BL; PPD, probing pocket depth; PI, plaque index.

Table 3. Non surgical treatment of peri-implantitis: interventions and main outcomes of the selected studies.

First autor, year	Follow up	n	Intervention	Probing Pocket Depth		Bleeding on Probing	
				Baseline	Final	Baseline	Final
Schar, 2012 (44)	6 m	20	TiC + Gly air-abrasive + Diode laser	4.19 (0.55)	3.83 (0.58)	4.03 (1.66)	1.51 (1.41)
		20	TiC + Gly air-abrasive+ MIN	4.39 (0.77)	3.90 (0.78)	4.41 (1.47)	2.10 (1.55)
Sahm, 2011 (42)	6 m	15	Carbon-fibre curette + CHX	4 (0.8)	3.5 (0.8)	95.3(9.6)%	84.3(15.5%)
		15	Gly air-abrasive	3.8 (0.8)	3.2 (0.9)	94.6 (15.8)%	51.1(24.7)%
Persson, 2011 (24)	6 m	21	Air-abrasive	6.2 (1.9)	6.2 (1.9)		
		21	Er:YAG laser	5.9 (1.7)	5.9 (1.7)		
Renvert, 2011 (33)	6 m	21	Air-abrasive	Change: 0.8 (0.5)			No BOP: 25%
		21	Er-Yag laser	Change: 0.9 (0.8)			No BOP: 30.9%
Persson, 2010		17	TiC	4.0 (0.8)	4.0 (0.8)	1.7 (0.6)	1.2 (0.7)
Renvert, 2009 (25, 37)	6 m	14	Ultrasonic device	4.3 (0.6)	3.9 (0.8)	1.7 (0.9)	1.4 (1)
Renvert, 2008 (31)	12 m	58 IOI	Carbon-fibre curettes + CHX	3.87 (1.16)	3.72 (1.02)	86.5 (20)	48.1 (21)
		37 IOI	Carbon-fibre curettes + MIN	3.85 (1.04)	3.55 (0.98)	89.2 (17)	63.5 (19)
Renvert, 2006 (30)	12 m	14	Carbon-fibre curettes +CHX	3.9 (0.3)	3.9 (0.4)	86 (14)	78 (13)
		16	Carbon-fibre curettes + MIN	3.9 (0.7)	3.6 (0.6)	88 (12)	71 (22)
Renvert, 2004 (32)	3 m	14	Carbon-fibre curettes +CHX	3.9 (0.3)	3.9 (0.3)	86 (14)	78 (13)
		16	Carbon-fibre curettes + MIN	3.9 (0.3)	3.5 (0.6)	88 (12)	71 (22)
Schwarz, 2006 (47)	12 m	8	Plastic curettes + CHX	Mod: 4.5 (0.8) Adv: 6.0 (1.3)	Mod: 4.3 (0.5) Adv: 5.6 (0.9)		
		10	Er:YAG laser	Mod: 4.6 (0.9) Adv: 5.9 (0.9)	Mod: 4.1 (0.4) Adv: 5.5 (0.6)		
Schwarz, 2005 (56)	6m	9	Plastic curettes +CHX	5.5 (1.5)	4.8 (1.4)	80	58
		10	Er:YAG laser	5.4 (1.2)	4.6 (1.1)	83	31
Karring, 2005 (15)	6 m	11	Carbon-fibre curettes	6.2 (1.6)	6.3 (2.2)	72.7	81.8
		11	Ultrasonic device	5.8 (1.1)	5.8 (1.2)	63.6	36.4
Buchter, 2004 (5)	4.5 m	14	Plastic curettes	5.68 (0.28)	5.4 (0.34)	0.63 (0.1)	0.5 (0.1)
		14	Plastic curettes + doxycycline	5.64 (0.32)	4.49 (0.29)	0.54 (0.1)	0.27 (0.1)

Table 4. Surgical treatment of peri-implantitis: interventions and main outcomes of selected studies.

AFS: Access flap surgery; IOI: Implants; B-TCP: Beta-tricalcium phosphate; AuB: Autologous bone; RMb: Resorbable membrane; NRMb: Non-resorbable membrane; PlasC, plastic curette; CHX, chlorhexidine; IPl, implantoplasty

First autor, year	Follow-up	n	Decontamination	Intervention	Probing Pocket Depth		Bleeding on Probing	
					Baseline	Final	Baseline	Final
Aghazade, 2012 (1)	12m	22	H ₂ O ₂ (3%)	AFS+ AuB	6.0 (1.3)	3.8 (0.2)	87.5(20.1)%	48.4(5.4)%
		23		AFS + Bio-Oss	6.2 (1.4)	3.3 (0.2)	79.4(28.9)%	26.7(4.7)%
Schwarz, 2012 (51)	24m	14	PlasC + saline Er: YAG laser	AFS + Ipla + BioOss + RMb	5.2 (1.5)	3.7 (1.1)	100 (0.0)%	45.1 (30.4)%
		10			4.9 (1.4)	3.8 (1.3)	96.6 (10.6)%	21.6(33.3)%
Schwarz, 2011 (53)	6m	15	PlasC + saline Er: YAG laser	AFS + IPla + BioOss + RMb	5.5 (1.8)	3.1 (0.6)	100 (0.0)%	45.0 (31.2)%
		15			5.1 (1.6)	3.4 (0.6)	93.3 (18.7)%	45.5 (33.0)%
Schwarz, 2009 (52)	48m	9	PlasC + saline	AFS + nanocrystal HAP	6.9 (0.6)	5.8 (0.7)	80%	48%
		11		AFS + BioOss + RMb	7.1 (0.7)	4.6 (0.9)	79%	28%
Schwarz, 2008 (55)	24m	9	PlasC + saline	AFS + nanocrystal HAP	6.9 (0.6)	5.4 (0.7)	80%	44%
		11		AFS+BioOss+RMb	7.1 (0.8)	4.7 (0.7)	78%	34%
Schwarz, 2006 (48)	6m	11	PlasC + saline	AFS + nanocrystal HAP	7.0 (0.6)	4.9 (0.6)	82%	30%
		11		AFS+BioOss+RMb	7.1 (0.8)	4.5 (0.7)	78%	28%
Romeo, 2005 (38)	24m	7	Metronidazol + tetracycline + saline	Resective surgery + IPla	5.79 (1.69)	3.58 (1.06)	2.83 (0.47)	0.61 0.67)
		10		Resective surgery	6.52 (1.62)	5.5 (1.47)	2.86 (0.35)	2.33 (0.74)
Khoury & Buchmann 2001 (16)	30m	7	0.2% CHX + citric acid H ₂ O ₂ + 0.9% saline	AFS + AuB	6.40 (0.90)	2.90 (0.60)	NR	NR
		11		AFS+ AuB + NRMb	6.70 (1.10)	2.80 (1.30)	NR	NR
		7		AFS + AuB + RMb	6.40 (0.90)	5.10 (1.20)	NR	NR
Ross-Jansaker, 2007 (41)	12m	29 IOI	H ₂ O ₂ (3%) + saline	AFS + Algipore + RMb	5.44 (1.78)	2.86 (2.00)	79.3%	21.6%
		36 IOI		AFS + Algipore	5.64 (1.84)	3.44 (1.58)	92.9%	25%
Deppe, 2007 (8)	20-236m	17 IOI	CO ₂ Laser	Resective surgery	5.70 (1.40)	3.40 (1.50)	2.80 (1.20)	1.80 (1.10)
		13 IOI		B-TCP + RMb	5.70 (1.40)	2.50 (1.40)	3.30 (0.60)	1.90 (1.00)
		16 IOI	Air abrasive	Resective surgery	6.20 (1.80)	4.30 (1.20)	2.70 (0.90)	1.10 (1.20)
		11 IOI		B-TCP + RMb	5.10 (1.70)	2.50 (1.10)	2.30 (1.40)	2.10 (1.40)

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