Ultrasonic vs. hand instrumentation in periodontal therapy: clinical outcomes

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Periodontal disease

The initial culprits in periodontal disease are an array of periodontal pathogens that can trigger dysregulated immune and inflammatory responses in host periodontal tissues, causing bone and periodontal attachment loss (81, 125). Associated with the development of periodontitis are endogenous and environmental factors, such as poor oral hygiene, smoking, stress, obesity, genetic variation and diabetes and other systemic diseases (157). One goal of periodontal nonsurgical therapy is to reduce the amount of tooth-associated biofilms and their biological products, such as endotoxins, antigens, enzymes and other tissue-irritating substances (54). This can be accomplished through changing the subgingival environment by scaling and root planing or by root debridement, with or without local delivery of antimicrobials and/or antiseptics, and/or the use of adjunctive systemic antimicrobials. This initial therapy usually does not target the microbial communities associated with other extracellular or intracellular mucosal niches within the mouth, or systemic colonies (84, 92). Although studies have shown saliva, cheek, tongue, tonsillar crypts and the palatal surface microbial colonies as additional sources of cross-infection to the periodontium within an individual, or among individuals (43, 45, 168, 171), nonsurgical therapy infrequently involves treating the whole mouth, or the whole body, or treating others in close oral contact with the patient, in an effort to control reinfection (11, 12). A statistically significant correlation exists between the presence of disease and the quantity and bacterial composition of dental plaque (11, 41, 42, 100, 156). Along with bacteria, cytomegalovirus, Epstein–Barr virus, papillomaviruses and herpes simplex virus may contribute to the pathogenesis of periodontitis (152). Such dual infections have been shown to be associated with more severe periodontal disease, as herpesviruses in general can enhance cytokine release, and Epstein–Barr virus, along with cytomegalovirus, are associated with more severe forms of periodontitis (24, 97, 140). Molecular methods have also revealed the presence of archaea and fungi within the subgingival milieu (19, 143).

Halting the progression of gingivitis

Plaque-induced gingivitis is an inflammatory change caused by accumulation of a bacterial biofilm on the tooth surface adjacent to the gingival tissues (98) and is the most common oral disease in dentulous adults (102, 123). Several studies have shown that this commonly occurring plaque-induced gingivitis is a precursor of periodontitis (94). Hugoson et al. (68) observed, in a cross-sectional study conducted in Sweden over a 30-year period, that improvements in plaque control reduced the prevalence of both gingivitis and periodontitis.

According to the classic model proposed by Page & Schroeder (124), the development of gingivitis and its progression to periodontitis occurs in four stages. Clinical signs of gingivitis start to appear in the ‘early lesion’ (second stage). Up to the ‘established lesion’ (third stage), clinical signs of the disease can be reversed by disrupting and removing the microbial plaque biofilm.

The most predictable way of disrupting the microbial plaque, reducing inflammation around the gingival margins and thus preventing gingivitis, is by...
mechanical disruption and removal of the microbial plaque community. The effectiveness of this procedure is highly dependent on the skill and ability of the individual to remove plaque from all the tooth surfaces (70). Several studies have investigated how frequently plaque needs to be removed to prevent gingivitis and reached different conclusions. Lang et al. (85) reported that brushing every 48 h prevents gingivitis, whereas Kelner et al. (75) reported that brushing every 24 h is consistent with gingival health. In addition, Kelner et al. (75) reported that brushing every 72 h does not prevent development of gingival inflammation. The subjects in these studies were dental students and their brushing technique was supervised by a dental hygienist, resulting in more plaque removal than average.

The European Workshop on Mechanical Plaque control (86) recognized that meticulous plaque removal every 24 h would be adequate to prevent gingivitis. However, because most people do not remove all the plaque on their tooth surfaces every time they brush, a higher frequency of toothbrushing will result in better plaque removal (2, 70). In 1995, The American Dental Association made the recommendation for toothbrushing to be performed at least twice a day (30, 66). In a more recent study carried out by Pinto et al. (128), participants were evaluated for gingival inflammation at baseline, and 15 and 30 days after performing mechanical removal of plaque with different frequencies of 12, 24, 48 and 72 h; the authors concluded that mechanical removal of plaque up to every 24 h may prevent an increase in the severity of gingival inflammation over a period of 30 days.

Disruption of microbial plaque every 12–24 h is ideal for preventing gingivitis. However, in certain situations in which the thoroughness of plaque removal is questionable, a higher frequency may be desirable.

**Calculus: an important secondary etiology**

Calculus, defined as mineralized bacterial plaque, is a gingival irritant, but bacterial plaque has a greater pathogenic potential than calculus (33). Calculus has both external irregularities and internal channels that can promote the retention of periodontal pathogens and therefore serves as a reservoir for inflammation-inducing microbial products and components (29, 162).

An early animal investigation showed that autoclaved calculus is only a low-grade irritant, whereas nonsterile calculus produces a granulomatous foreign body reaction with a tendency for abscess formation within connective tissue (5). In addition, Listgarten & Ellegaard (96) found that lowering the toxicity of calculus by treatment with chlorhexidine gluconate permits the attachment of a junctional epithelium to calculus.

It was once believed that plaque, calculus and cementum contaminated with bacterial products and components (e.g. endotoxin) required removal by thorough scaling and root planing to achieve periodontal health. Hatfield & Baumhammers (62) stated that root surfaces exposed to periodontal disease are toxic to growing cells in vitro, and Aleo et al. (3, 4) showed that endotoxin from periodontally involved teeth was toxic to fibroblasts, inhibiting their growth.

Nabers (112) advocated removing softened and contaminated root surface in order to obtain a smooth, hard surface that would allow reattachment to occur, and Jones & O’Leary (71) promoted root planing as able to render diseased root surfaces approximately as free of detectable endotoxin as uninvolved, healthy root surfaces.

The current general consensus among clinicians and clinical researchers is that cementum, although difficult to retain during calculus removal, need not be sacrificed for a good therapeutic outcome (117). It appears that endotoxin adheres to root surfaces without penetration into cementum, and its binding to root surfaces appears to be weak (113).

Root planing with hand instrumentation is able to remove root irregularities that harbor plaque and calculus, and renders diseased root surfaces free of detectable endotoxin (67, 71). However, it has been shown that gentler techniques, utilizing sonic or ultrasonic scalers, are as effective in removing plaque and calculus (110).

**Hand instrumentation vs. sonic/ultrasonic instrumentation**

Altering the subgingival microbiota to one compatible with periodontal health, or reducing the bacterial load and calculus deposits on tooth surfaces, can be achieved with equal effectiveness by hand scalers and curettes or ultrasonic scaling instruments (14, 15, 27, 46, 48).

Root debridement is often performed with a combination of sonic and ultrasonic instruments and hand instruments (such as scalers and curettes), followed by root planing with hand instruments. There are two
basic types of curettes – Universal and Gracey – with most models requiring sharpening. These two types of curette differ in the area-specificity, the number of cutting edges, the curve of the cutting edge and the angle of the face to the terminal shank.

The success of periodontal therapy depends on the removal of hard and soft deposits from the root surfaces (16, 17, 65, 95). Reviews of various studies performed under different conditions and in different models have concluded that neither hand nor mechanical instruments are superior in removing subgingival deposits (36, 47, 88, 89, 118, 121, 159). Ultrasonic instruments remove less root structure than hand instruments (158, 164) but leave behind a rougher surface (20). Hand instrumentation has been recommended to smooth the root surface after ultrasonic use as a final finishing procedure in the treatment of periodontitis-affected roots (139).

Most commercially available hand instruments require sharpening on a regular basis. For decades it has been accepted knowledge that periodontal instruments must be re-sharpened frequently (37, 119, 161, 177). A few studies have compared changes in root-surface morphology based on the cutting edge of the instruments used (20, 21, 119, 138). O’Leary & Kafrawy (119) recommended sharpening hand instruments after every five working strokes, Coldiron et al. (47) after every 10 strokes and Rees et al. (133) after every 12 strokes. Zappa et al. (180) found that after the first 20 strokes there was diminished hard-tissue removal and an increase in pressure applied per stroke. Even though all these studies show a decrease in instrument sharpness and effectiveness, very few clinicians sharpen their instruments every five to 20 strokes (180). Although instrument sharpening is the deciding factor for clinical effectiveness in achieving a clean and smooth root surface, sharpening the instrument every five to 20 strokes is not very practical and results in destruction of the original contour of these expensive instruments. Re-sharpening can weaken the scaler, causing breakage during function, or can create metal tags that are potentially harmful to the hard and soft tissues. All studies evaluated so far still leave us with the question of how frequently we should sharpen our instruments. How much is too much and how much is too little? Most studies suggest that depending on the quality of the alloy and the pressure used for root planing, we may be able to retain sharpness for a greater number of strokes than originally thought.

Owing to the above problems with instrument sharpening, clinicians and instrument manufacturers have been seeking instruments that can achieve better clinical effectiveness with less trauma to the hard and soft tissues and can be used for prolonged periods of time without sharpening. Several instruments with “edge retention” properties have been recently introduced to the market with the claims that these instruments need little or no sharpening, and allow unproblematic maintenance and display long-term effectiveness. Different metal alloys, including stainless steel, high-speed steel, carbon steel and tungsten carbide, have been shown to influence the efficacy and life expectancy of the instrument (160).

Sisera et al. (151) evaluated three different instruments with edge-retention technology in comparison with a standard curette made of stainless-steel alloy. They simulated clinical conditions in the laboratory using bovine central incisors. The concurrent removal of dental hard tissue, at predetermined intervals (i.e. number of strokes), was evaluated to monitor the effectiveness and hard-tissue damage caused by the instruments. The surface roughness after use was also assessed. The influence of the sterilization process, which may harm the curette material by changing the structural components, was also assessed. Of the three instruments tested, two had titanium nitride coating and one was made of cryogenically treated stainless steel. Instruments and the root surfaces were evaluated at baseline, after 500, 1000 and 1010 strokes, and after sterilization. The authors found no statistically significant difference between the different instruments at different time points regarding the amount of tooth structure removed. After 1010 strokes and five sterilization cycles, the dentin removal significantly decreased for all curettes (P ≤ 0.05). It was concluded that although the manufacturers’ claim for the titanium nitride-coated instruments and the tempered stainless-steel instrument about not requiring frequent sharpening over multiple usage was true, it was also true for the control curette, which was made of untreated stainless steel alloy. All instruments lost efficacy after being repeatedly treated with thermal and chemical sterilization. Another recent study examined the effect of repeated dry-heat sterilization and autoclave cycles on carbon-steel and stainless-steel curettes during scaling and root planing. Carbon-steel curettes were more likely to be affected by surface corrosion products and edge deterioration than were stainless-steel curettes. Using 2% sodium nitrite to inhibit corrosion before sterilization greatly reduced the oxidation of the metal surface (129).

Recently, diamond-coated curettes have been introduced for scaling and root planing with conven-
tional curettes. Eick et al. (50) evaluated the efficacy of an additional use of diamond-coated Gracey curettes on surface roughness, adhesion of periodontal ligament fibroblasts and detection of Streptococcus gordonii in vitro after conventional root planing. The curettes used were diamond coated at the working ends with a 15 μm grit size of natural diamond granulate. The authors found that the additional instrumentation with the diamond-coated curettes resulted in a two-fold increase in the number of attached periodontal ligament fibroblasts but not in the numbers of adhered bacteria. The authors concluded that conventional root planing with Gracey curettes followed by subsequent polishing with diamond-coated curettes, may result in a root surface that provides favorable conditions for adhesion of periodontal ligament fibroblasts without increasing microbial adhesion (50). However, this study did not evaluate the instruments for their ability to remove calculus, but rather evaluated the effect of the instruments on root-surface properties.

Only a limited number of studies have examined the differences, between instruments, in retention of the cutting edge (151, 160, 161). Several studies have compared stainless-steel instruments with those of carbon steel, to see how the alloy mix affects the hardness of the cutting edge, and have reported conflicting results. In the study carried out by Tal and coworkers (160, 161), the stainless-steel curettes showed significant edge attrition after 45 strokes compared with the high-speed steel, cemented-carbide steel and high-carbon steel instruments. Gorkhovsky et al. (57) showed significantly less wear on instruments with a 10 multilayer titanium nitride/titanium coating compared with uncoated high-chromium stainless-steel scalers – wear resistance of the former was increased by at least 12.5 times and clinical usefulness extended from 3 months to 6–11 months, depending on the rate of use. They also found that steam sterilization at 260°C for 30 min and 215 cycles of ultrasonic cleaning had no negative effects on either the titanium-coated or stainless-steel curettes.

Dentin removal and surface roughness have been examined in earlier instrumentation studies (51, 72, 105, 107, 126, 167, 178). Benfenati et al. (20) analyzed scanning electron microscopy images of root surfaces and found that blunt instruments produced smoother root surfaces compared with sharp instruments, even though they did not completely remove all the deposits on the root surface. A damaged curette created deep scratches on the root surface. In more recent studies, curettes have proven to create a relatively smooth surface morphology, as determined by profilometric findings (145, 169).

Powered scalers utilized in debridement procedures are classified into sonic and ultrasonic instruments according to their working frequencies. The frequency (or speed) and the amplitude (or length) of the stroke are important parameters to consider when using ultrasonic scalers. The power setting that is normally tuned manually controls the length of the stroke, or amplitude. It has been shown that vibration displacement amplitude at the scaling tip is equally effective in scaling efficiency at half power or full power (69). However, the chipping action, which not only removes calculus but can damage root structure, is greater at higher power settings (87). Also, the tip displacement amplitude at a medium power setting of 5 or 6 is higher with piezoelectric scalers than with magnetostrictive units. This observation supports the findings of Busslinger et al. that piezoelectric devices create a higher degree of root damage compared with magnetostrictive scalers running at the same power setting (28, 52, 53). The greater the frequency, the higher the energy output but the smaller the active area of the tip. A lower frequency, of 25 kHz, results in an active area of 4.3 mm at the terminal tip, whereas a higher frequency, of 50 kHz, will result in an active area of only 2.3 mm. At low frequency under a load of 25 g, the active area of the tip is increased, allowing deeper pocket depths to be reached with diminished generation of heat, thus preventing thermal damage and patient discomfort (88). Sonic powered instruments operate at frequencies in the sonic range of 2–8 kHz (cycles per second) and are driven to vibrate by compressed air striking a metal rod within the handpiece to produce audible oscillations that travel down to the attached scaling tip. The vibrating tip produces elliptical to orbital motions with all sides of the tip able to adapt to the root surface (55, 93). The two types of ultrasonic scalers are based on either magnetostrictive (e.g. Cavilon®) or piezoelectric (e.g. Piezon Master 400®, Symmetry IQ®) mechanisms. The magnetostrictive ultrasonic instruments are driven to vibrate by an electric current supplied to either a wire coil, metal stacks made of nickel–iron alloy, or to a ferrous rod in the handpiece, producing a magnetic field that causes the oscillation generator to change shape or dimension, creating the high vibrational energy that travels to the scaler tip (10, 47). The piezoelectric scalers use electrical energy to electrolyse crystals housed within the handpiece. The dimensional changes of these crystals cause the generation of high vibrational energy that travels to the tip (53). Magnetostrictive
ultrasonic scalers have elliptical tip movement and operate between 18,000 and 45,000 cycles/second, much faster than sonic scalers, with an amplitude that ranges from 10 to 100 μm. All surfaces of the tip – front, side and back – are simultaneously active with the elliptical vibratory movement (53). The metal stack in the magnetostrictive scaler generates heat, and to prevent overheating it requires plenty of irrigation during scaling. It is recommended that the flow rate be at least 20–30 ml/min to prevent a temperature increase of more than 5°C that could potentially damage the pulp and dentin (115). Piezoelectric devices do not generate much heat and require less irrigant; however, the cooler water might cause more sensitivity during the procedure. Magnetostrictive scalers have tips that are interchangeable as long as the unit is of the same frequency, whereas piezoelectric tips are of proprietary design and therefore are not interchangeable. When using the magnetostrictive ultrasonic scaler to remove heavy calculus deposits on supra- and subgingival sites, it is best to use a large tip on medium to high power. In subgingival sites, the tip should be introduced to the base of the pocket, moving coronally with paintbrush and light-pressure strokes that are parallel to the long axis of the tooth. At the feel of a calculus ledge, the tip should be moved to the coronal aspect of the calculus and tapped in an apical direction to break it away from the surface of the root. Thin tips on medium to high power are used to remove hard calculus from furcations, concavities and deeper pockets. Thin tips made of especially filtered titanium nitride/stainless-steel alloy can sustain high power without breaking. It is important to follow power debridement with sharp hand instruments, such as Gracey curettes, to remove any residual calculus and smooth the root surface.

Piezoelectric ultrasonic scalers produce a linear vibratory movement that permits two lateral sides of the tip to be active, operating at 25,000–50,000 cycles/second, with amplitude of 12–72 μm. The recommended technique for using the piezoelectric scaler is from a coronal to apical direction. The crown of the tooth should be paintbrushed, with the tip held lateral to the tooth surface, using light pressure and overlapping strokes moving down to the base of the pocket, always with the lateral side of the tip parallel as possible to the long axis of the tooth. The vibration patterns and frequency of piezoelectric and magnetostrictive scalers facilitate the dispersal, crushing and removal of calculus with a continuous water coolant (88). Although the primary mode of operation is the physical vibratory action of the oscillating tip, the irrigant not only provides cooling at the treatment site, but creates acoustic turbulence, streaming and cavitation. Extreme conditions of pressure and temperature that destroy cell walls and kill bacteria are produced by the cavitation resulting from the formation and break down of microscopic bubbles (cavities) created as water passes through the handpiece. Water exiting the tip creates acoustic microstreaming and turbulence, further agitating and disrupting the content of the pocket. Microjets that impact on the tooth surface aid in the removal of plaque and stain but can also produce pitting in an area of 0.66 mm² (47, 83, 172–175).

Increased loading with tips contacting the tooth at 0.25–1.0 N (or 25–100 g) demonstrated a nonlinear increase in displacement amplitude, which was significantly different from the unloaded tip response, suggesting high variability associated with ultrasonic inserts because specific power levels are required for different tips to achieve the same level of calculus and plaque removal (87).

Another explanation for variability in tip performance is reduction in tip length from repeated clinical use and wear. A 1 mm reduction in wear results in close to 25% loss of efficiency, whilst a 2 mm reduction in wear reduces the vibration displacement amplitude by approximately 50%, requiring immediate tip replacement. Scaler tip wear is reduced by diamond coating. The diamond tips have been shown to remove calculus rapidly, especially at furcation areas. However, they also lead to increased overall root-surface removal (169).

Even though earlier studies have shown that ultrasonic scaling was enhanced by irrigation with povidone iodine, resulting in attachment gains of 50% more than those receiving either ultrasonic debridement alone or periodontal surgery, randomized clinical trials by Del Peloso Ribeiro et al. (42) and Leonhardt et al. (91) found no additional benefits in using either a 0.5% or a 10% solution of povidone iodine as an irrigant during debridement with ultrasonic devices. A study describing the use of 0.12% chlorhexidine gluconate as an irrigant during subgingival ultrasonic scaling demonstrated no enhanced clinical outcomes (31), and a second study showed a significant reduction in pocket depth at a 28-day recall examination, suggesting that certain antimicrobial irrigants may enhance ultrasonic debridement (134). No studies have been published using 0.5% sodium hypochlorite as an adjunct irrigant during ultrasonic debridement.

A systematic review of controlled clinical trials, with 6 months or more of follow up, assessed the differences between ultrasonic, sonic and manual debride-
ment for the treatment of chronic periodontitis. It was found that the mean gain in clinical attachment level, the mean reduction in probing depth and the mean reduction in bleeding on probing were similar for both machine-driven and hand instruments. Procedures using machine-driven instruments, however, took significantly less time (36.6% less than hand instrumentation) and caused less soft-tissue trauma but more root damage (165). A second systematic review, carried out by Needlemann et al. (114), assessed supragingival and subgingival plaque removal using hand instruments (scalers and curettes) and powered instruments (sonic, ultrasonic, rotating devices and air-polishing devices). They found that repeated oral-hygiene instructions showed similar effects to professional mechanical plaque removal using either technique.

Early investigations demonstrated that hand instrumentation by curettes, as well as by very fine rotating diamonds, created the smoothest root surfaces, whereas “vibrating” instruments, such as sonic and ultrasonic scalers, as well as coarse diamonds, tended to roughen the root surface (144). Cobb (35) found manual curettes more technique sensitive and time consuming but more efficient with increased probing depths. Equivalent clinical outcomes, however, have been shown in studies comparing ultrasonic units with hand scaling. A mean probing-depth reduction of 1.2–2.7 mm was observed with the use of ultrasonic instruments, and values similar to those were obtained with conventional hand instrumentation, showing a reduction of 1.29 mm for moderate pockets and 2.16 mm for deep pockets (36, 47). According to a systematic review conducted by Van der Weijden & Timmerman (166), subgingival mechanical instrumentation resulted in a mean attachment gain of 0.30–1.02 mm in pockets with an initial depth of up to 4 mm and a mean attachment gain of up to 1.58 mm in pockets with an initial depth of ≥7 mm.

The literature on the physical effects of magnetostrictive and piezoelectric ultrasonic scaling devices on tooth surfaces has shown varying results. For example, Flemmig et al. (52) reported that use of a magnetostrictive scaler for root debridement resulted in a rougher root surface compared with use of a piezoelectric device. By contrast, Busslinger et al. (28) showed that after root instrumentation, a piezoelectric device left a rougher surface than a magnetostrictive device. A recent study showed that root surfaces treated with a piezoelectric scaler using 200 g of lateral force were smoother than those treated with a magnetostrictive device with the same lateral force (179).

Comparison of root-surface instrumentation using manual curettes, magnetostrictive ultrasonic scalers and rotary instruments demonstrated nonsignificant differences between the three groups in the amount of calculus remaining, loss of tooth substance and roughness of root surface after root planing; however, magnetostrictive ultrasonic scaling showed the lowest mean scores for the roughness/loss of tooth substance index, indicating less removal of cementum and fewer marks of instrumentation on the dentin surface (101). Kawashima et al. (74) compared the effectiveness of two piezoelectric ultrasonic scalers and a hand scaler for subgingival scaling and root planing in vivo and found similar results, showing that the remaining calculus index did not differ significantly among the groups but the roughness/loss of tooth substance index was significantly lower for the groups treated with the piezoelectric ultrasound unit.

Manul and ultrasonic scalers have been shown to be equally effective in subgingival plaque removal. Oosterwaal et al. (121) showed equal outcomes in reducing the counts of rods, spirochetes and motile organisms with either manual or ultrasonic magnetostrictive scaling on the subgingival microbiota in periodontal pockets with probing depths of 6–9 mm.

Baehni et al. (18) compared the effects, on the subgingival microbiota, of scaling using a piezoelectric instrument with scaling using a sonic instrument and reported no differences between the two techniques in microscopy or culture observations.

The efficacy of ultrasonic scalers on the removal of endotoxin has also been investigated. Nishimine & O’Leary (116) found that ultrasonic scaling resulted in average residual endotoxin values (i.e. 16.8 ng/ml) approximately eight times higher than those after hand scaling (i.e. 2.09 ng/ml). Smart et al. found endotoxin levels of <2.5 ng per root after debridement with a magnetostrictive ultrasound unit, which was enough to allow fibroblast reattachment (155).

Several investigators have reported that ultrasonic instruments can save 20–50% of time used for periodontal debridement (32, 35, 49), and cause less discomfort to the patient, while showing equal healing responses of the affected periodontium (145, 165, 176). In addition, debridement using ultrasonic instrumentation has been shown to be more effective in areas of limited access, such as in furcations, deep vertical defects or any area with limited access (49).

Comparison between hand instruments and sonic and ultrasonic scalers did not show a clear advantage for the machine-driven instruments (165), and tissue trauma was similar with both instruments (6). Hand instruments yielded greater improvements in clinical
parameters, such as bleeding on probing, compared with instrumentation using an ultrasonic system (34). Use of conventional Gracey curettes may result in higher substance loss, but significantly better calculus removal (26, 79, 145) and smoother surfaces, compared with sonic and ultrasonic instrumentation (26, 79, 80, 135).

Around implant abutments, studies have observed that the use of plastic and titanium curettes resulted in smoother surfaces compared with the use of steel curettes (106). Several studies have confirmed the finding that hand instrumentation produced much smoother surfaces with fewer irregularities and grooves compared with sonic and ultrasonic instruments (13, 107).

Apart from producing a smooth surface free of bacteria, another goal of scaling and root planing is to facilitate fibroblast cell attachment on the root surface. Studies have shown that a very low number of fibroblasts attach on untreated root surfaces with periodontal disease (15, 76). Studies in which diode lasers were used did not report an increase in the numbers of attached cells after scaling and root planing (82).

Ultrasonic scaling in combination with a CO₂ laser was compared with hand scaling and root planing; more pronounced fibroblast attachment was found with the additional use of a CO₂ laser (39). Similar results of increased fibroblast attachment were also found in a study investigating the effect of using erbium-doped yttrium aluminium garnet (Er:YAG) lasers (149). In contrast, some studies have found no difference between rotary instruments and hand scaling (77). In the study by Eick et al. (50) the number of fibroblasts attached doubled when the surface was treated with diamond-coated curettes. The fibroblast orientation suggested that moderate roughness of the root surface was beneficial for cell attachment. Eick et al. (50) did not find any additional bacterial adhesion after instrumentation with diamond-coated curettes compared with Gracey curettes alone. More studies are needed to evaluate the relationship between bacterial adhesion and the attachment of fibroblast cells on root-surface roughness.

The roughness of the root surface after a scaling procedure is a factor to consider for maintenance because it has been shown that bacterial plaque adheres more easily to rough root surfaces than to smooth root surfaces (78, 89). Studies have shown that initial bacterial adhesion always occurs on surface irregularities (130). However, a study comparing hand instrumentation with Er:YAG lasers and ultrasonics showed that the roughest root surface with the greatest amount of adhesion of Streptococcus sanguinis was obtained after hand instrumentation (122).

Schwarz et al. (146) published a systematic review that discussed the clinical effect of laser application compared with mechanical debridement in patients undergoing nonsurgical periodontal therapy. They also reviewed existing literature in relation to the safety of laser applications. Owing to the heterogeneity of the different articles reviewed, they were not able to perform a meta-analysis. However, based on the limited evidence available, they concluded that both Er:YAG lasers and mechanical debridement yielded similar results, both short term and long term (up to 24 months). Miyazaki et al. (108) compared the effect of CO₂ and neodymium-doped yttrium aluminium garnet (Nd:YAG) laser monotherapy with that of ultrasonic scaling, and reported significant reductions in probing depths in all treatment groups after 1, 4 and 12 weeks of healing. However, only the Nd:YAG group and the ultrasonic group showed significant reductions in bleeding on probing and gain in clinical attachment level. Aoki et al. (7) reported that neither CO₂ nor Nd:YAG lasers were able to remove root surface calculus satisfactorily and that they produced root-surface alterations as a result of heat generated during irradiation. Studies evaluating Er:YAG laser monotherapy for initial (38, 44, 147, 148, 150) or maintenance (163) therapy have shown considerable improvements in all periodontal clinical parameters after treatment. The microbiological results reported by Schwarz et al. (147, 148) indicate that subgingival bacteria repopulate periodontal pockets 3–6 months after treatment with Er:YAG lasers, indicating that there are no additional benefits of using lasers over conventional therapy.

Bower (25) has shown that in 81% of maxillary and mandibular molars the furcation entrance is 1.0 mm or less, and in 58% the diameter is 0.75 mm or less. The blade face-width of curettes used in scaling and root planing ranges from 0.75 mm to 1.10 mm, limiting movement of the blade within a space of the same size (25). Leon & Vogel (90) showed that in Class I furcations, hand scaling and ultrasonic debridement have equivalent access and consequent effects on microbial outcome, whereas in Class II and Class III furcations, ultrasonic debridement is significantly more effective than hand scaling in decreasing the counts of motile rods and spirochetes and in maintaining decreased bacterial counts in these sites. Significantly thinner ultrasonic tips, measuring 0.55 mm, are smaller than the working ends of the smallest curettes, making them a superior choice for calculus removal at moderate and severe furcation...
sites. In favor of sonic or ultrasonic instruments, a reduction in the quantity of bacteria will create a balance between the host response and the residual organisms, leading to good therapeutic outcome (27).

Traditional periodontal therapy involves scaling and root planing, one quadrant at a time, with a 1-week interval between appointments. This kind of treatment, whilst effective, does not reduce the overall burden of microbes in the oral cavity and there is always a chance of cross-infection between treated and untreated sites. To address this problem, in 1995, Quirynen et al. (131) introduced the concept of full-mouth disinfection. In this procedure, full-mouth scaling and root debridement were performed within a 24-h period, subgingival irrigation (repeated three times within a 10-min period) was carried out with 1% chlorhexidine gel, the tongue was brushed with 1% chlorhexidine gel and the mouth was rinsed with 0.2% chlorhexidine. Quirynen et al. (131) showed that this yielded a better short-term result than the conventional treatment protocol for periodontal disease. However, conflicting findings have been reported regarding the benefits of scaling and root planing, or root debridement, according to quadrants, over a number of visits, compared with one-stage full-mouth instrumentation. It has been shown that nonsurgical instrumentation performed in one visit, or quadrant scaling performed in days, or weeks, had no significant impact on the treatment outcome (8, 141).

The limited additional benefits of full-mouth debridement include a shorter treatment time and use of less material in the clinic, but at the expense of time needed to optimize home oral-hygiene protocols and to develop a strong patient/practice relationship to encourage patient compliance with oral-hygiene protocols. It is well established that the absence of good oral hygiene will result in the repopulation of deep pockets 4–8 weeks following subgingival instrumentation. Hence, good plaque control can suppress repopulation of previously treated subgingival sites and affect the microbial populations in periodontally involved sites that were not treated. Optimal oral hygiene is key to successful nonsurgical therapeutic outcomes (99, 111).

Can antimicrobial therapy be effective if the biofilm is not mechanically disrupted?

Studies have shown that bacterial resistance is much higher in biofilms. Several authors have also suggested that the minimum inhibitory concentration profiles are different for bacteria in biofilm than for bacteria in the planktonic state (22, 120, 181). This could be a result of the fact that bacteria in biofilm exist in different physiological stages of their life cycle. The biofilm also contains different species of bacteria, protozoa, fungi and viruses; communities composed of hundreds of interacting species that, once established, survive in the crevicular environment and challenge the innate, inflammatory and adaptive immune responses that are unable to clear or completely remove the biofilm (9, 109). Also, the biofilm matrix is composed of complex polymers inhibiting penetration and distribution of molecules toward the central region containing the most viable bacteria. The disruption of biofilm by mechanical debridement and the establishment of daily oral-hygiene practices are central features of effective nonsurgical periodontal therapy, possibly by rendering this intricate biofilm community more susceptible to adjunctive approaches (9).

A systematic review (60) that focused on the use of antimicrobials as an adjunct to mechanical debridement and surgical therapy, as well as when used as a monotherapy, concluded that the use of antimicrobials as a monotherapy did not produce any significant improvements in clinical outcomes and concluded that “there was insufficient evidence to support the use of antibiotics as a monotherapy in periodontitis patients”. The American Academy of Periodontology position paper on systemic antibiotics in 1996 suggested that based on the concept of “good medical practice”, mechanical debridement should always precede medications (1). This conclusion was also supported in a review by Slots (153). A systematic review conducted in 2008 (63), which attempted to assess the benefits of prescribing antibiotics during the nonsurgical therapy phase vs. the surgical phase, remained inconclusive. However, two studies (58, 73) that were not included in the above review showed better clinical outcomes when a combination of amoxicillin and metronidazole was given to a group of patients with generalized aggressive periodontitis during the initial therapy phase, and a synergistic effect against the causative bacteria, Aggregatibacter actinomycetemcomitans, has been noted in vitro with a combination of metronidazole and amoxicillin (127).

Periodontitis is an infection and the causative microorganisms often invade other tissues in the body. These microbes adhere to the surfaces of teeth in a very organized and complex manner to form a biofilm called dental plaque. At the 5th European
Workshop of Periodontology, it was concluded that “Dental plaque displays properties that are typical of biofilms and microbial communities in general, a clinical consequence of which is a reduced susceptibility to antimicrobial agents as well as pathologic synergism” (104). In a systematic review presented at the European Workshop in 2002, Herrera et al. (64) concluded that in certain clinical situations, such as in patients with deep pockets, with progressive or refractory disease, or with specific microbial profiles, the use of adjunctive systemic antimicrobials may be beneficial. In another systematic review, presented at the World Workshop in 2003, Haffajee et al. (60) concluded that even though systemic antibiotic therapy could somewhat help conventional periodontal therapy, because of the absence of a well-defined protocol, it was prudent to stick to conventional mechanical therapy alone.

Povidone-iodine, dilute sodium hypochlorite and chlorhexidine gluconate have been used for pocket irrigation during, or following, root-debridement procedures with the intent of applying bactericidal agent in areas where root planing is less than ideal as a result of anatomy or local factors. Locally applied antimicrobial systems containing minocycline, doxycycline, tetracycline, metronidazole and chlorhexidine have been used with the intent of reducing the numbers of viable pathogens in biofilms and suppressing the reformation of biofilms (23, 56, 59). The delivery of local antimicrobial therapy, alone, or in conjunction with scaling and root planing, has been reviewed in a meta-analysis by Hanes & Purvis (61). In this analysis, they compared 19 studies that used adjunctive local-delivery antimicrobials, such as minocycline gel, microencapsulated minocycline, chlorhexidine chips and doxycycline gel, and found significant probing-depth reduction and clinical attachment gain when compared with scaling and root planing alone. The use of sustained-release anti-infective agents has been shown to reduce probing depths and bleeding on probing in some populations, similarly to that achieved by scaling and root planing alone (24, 61). The use of antimicrobial irrigants or anti-infective sustained-release systems did not show any significant adverse effects on patients. Although some studies have shown that chlorhexidine irrigation during scaling and root planing, compared with scaling and root planing alone, did not have a positive adjunctive effect (40, 132), povidone-iodine (Betadine®, Iodopax®) showed positive adjunctive effects, both in clinical indices and microbial parameters. In addition, use of sodium hypochlorite (0.1–0.5%) showed an 80-fold reduction of root endotoxin in teeth with periodontal disease, to a level comparable with that of periodontally healthy teeth (142). A study performed in dogs showed that irrigation with sodium hypochlorite resulted in histological signs of increased osteoblastic activity, even though overall healing and pocket-depth reduction was equal to that obtained by scaling and root planing alone (170). It is important to note that chlorhexidine has the potential to induce a dose-dependent reduction in fibroblast proliferation and, at lower concentrations, to alter the production of collagen and noncollagen protein by these cells (103). A potentially adverse effect of povidone-iodine is that it can interfere with thyroid metabolism, especially in patients with thyroid dysfunction. Prolonged exposure to iodine can cause goiter, alter synthesis of thyroid hormones, or induce myxedema or hyperthyroidism (154). A mixture of sodium bicarbonate, sodium chloride, and hydrogen peroxide, in conjunction with scaling and root planing, has been shown to reduce the microbiota and arrest the breakdown of periodontal tissues, and to promote early periodontal healing with gain in attachment levels and gain in alveolar bone mass (136, 137).

When sites of inflammation have not responded to initial periodontal therapy, advanced periodontal therapy and/or periodontal maintenance therapy, locally delivered antibiotics can be used. Locally delivered antimicrobials are placed in a periodontal pocket with a delivery system and released in a controlled manner, allowing the minimum inhibitory concentration of the antimicrobial to be achieved for a prolonged period of time. Local antimicrobials include: Atridox®, a 10% doxycycline gel in a bioabsorbable mixture that, when placed below the gingival margin, flows to the bottom of the pocket, adapts to the root surface and releases active drug over a period of 21 days; PerioChip®, a 2.5 mg chlorhexidine biodegradable chip that is placed in the periodontal pocket and maintains activity for up to 7–10 days; and Arestin®, a powder containing 1 mg of minocycline spheres that remain active in the pocket for up to 14 days. A 2003 workshop on periodontitis found statistically significant improvement in clinical attachment levels with adjunctive use of Atridox or the PerioChip combined with scaling and root planing (61) and Grossi et al. (59) found that compared with scaling and root planing alone, the use of minocycline microspheres significantly improved probing depths, clinical attachment levels and bleeding on probing, and resulted in a reduction of red complex bacteria in smokers with chronic periodontitis.
Concluding remarks

Nonsurgical periodontal therapy involves mechanical removal and disruption of bacterial colonies from the tooth and root surfaces. This can be accomplished by hand, sonic and ultrasonic scalers. Root planing with hand instruments render remove the root irregularities that harbor plaque and calculus. Root planing with sonic and ultrasonic instruments remove less of the tooth structure, but leave behind a rough surface. However, both techniques are equally effective in removing plaque and calculus deposits.

Sharp hand instruments are the key factor for clinical effectiveness. It is recommended that the hand instruments be sharpened every five to 20 strokes. However, this is not practical, creates metal tags and changes the original contour of the instruments. Instruments also lose their efficacy after repeated thermal and chemical sterilization. In view of these problems, instruments with “edge retention” properties have recently gained popularity.

Powered scalers increase the efficiency during nonsurgical periodontal therapy by reducing operator fatigue and removing calculus more quickly than hand instrumentation. However, powered instruments create a rough root surface and increase root sensitivity. Powered instruments are classified as sonic and ultrasonic based on their working frequencies. The frequency, speed and amplitude are important parameters to consider whilst using the power-driven scalers. Higher frequencies require higher energy output, but result in a smaller active area around the tip. Ultrasonic devices can be piezoelectric or magnetostriuctive. Understanding their mechanism of action helps the clinician use them optimally and reduces the damage to the tooth structures and surrounding tissues.

Chemical irrigation with antimicrobials as an adjunctive therapy has been shown to have added benefits during nonsurgical periodontal therapy. Antimicrobial agents, such as povidone-iodine, dilute sodium hypochlorite and chlorhexidine gluconate, have been used for pocket irrigation during, or following, root debridement because of their potential bactericidal effect. Other local antimicrobials used include minocycline, doxycycline and metronidazole.

Nonsurgical therapy can be accomplished in a single visit or in multiple visits. The advantages of using a multivisit approach are that the clinician has multiple opportunities to observe and correct the oral-hygiene practices of the patient and to evaluate and treat any sites needing additional therapy. A single-visit full-mouth disinfection procedure before scaling and root planing, quadrant by quadrant, helps to reduce the overall bacterial load and has been shown to have additional benefits.

Nonsurgical treatment is the keystone to successful treatment of any patient with periodontal disease. It is important for the clinician to understand the different instruments used, adjunctive therapies available and the best practices established in order to achieve optimal results.

References

Ultrasonic vs. hand instrumentation in periodontal therapy


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