Literature Review

The Dental Water Jet: A Historical Review of the Literature

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Abstract

Purpose: The objective of this paper is to provide a broad overview of the predominant findings from research published on pulsating dental water jets over the last 45 years.

Method: The author performed a computerized MEDLINE search covering the years from 1962 to 2009, with 1962 chosen since it was the year the first dental water jet was introduced. Key words included "oral irrigator" and "oral irrigation." All past and current studies were reviewed and those that reflected original research were included. The article is not intended to provide an exhaustive detailed article review, but rather a broad review of predominant findings on currently available traditional pulsating dental water jets with no novelty features. The author makes no attempt to statistically analyze any of the data. Information reported in the article comes from the original investigator analysis and interpretation.

Results: The dental water jet is supported by a well–established body of evidence demonstrating the ability to remove plaque, reduce periodontal pathogens, gingivitis, bleeding and inflammatory mediators.

Conclusion: The dental water jet is a viable tool for reducing bleeding and gingivitis in a wide variety of patients. Due to the extensive body of knowledge on this product, a meta–analysis or systematic review is warranted. Additional research is recommended to confirm plaque biofilm removal, its effectiveness in comparison to flossing and efficacy on patients with special oral or systemic health needs.

Key Words: bacteremia, dental water jet, depth of delivery, inflammatory mediators, pulsation, pressure, oral irrigation

This study supports the NDHRA priority area, Clinical Dental Hygiene Care: Investigate how dental hygienists use emerging science to reduce risk in susceptible patients (risk reduction strategies).

Introduction

Since its debut in the 1960s, the dental water jet has been studied in numerous clinical trials. Consistent positive outcomes focus on the reduction of bleeding and gingivitis.[1–23] Patients with varying needs, from those in periodontal maintenance[9,11–14,17,19] or orthodontic appliances,[6,16,23,24] to people with diabetes,[20] implants,[18] crowns and bridges[1] and non–compliance with floss have been shown to benefit.[22,23] This is different from a toothbrush or dental floss where efficacy is generally measured by supragingival plaque removal.[25]

Mechanism of Action

Pulsation and Pressure

The physical action of the dental water jet centers on 2 critical components – pulsation and pressure. This combination provides for phases of compression and decompression of the tissue to help expel subgingival bacteria and other debris, as well as stimulate gingival tissue.[26–28] Studies have shown that a pulsating device was 3 times more effective than a continuous stream device.[26,27]

Pulsation allows for the regulation of pressure. Bhaskar et al showed that attached gingiva can withstand high amounts of pressure – up to 160 psi for up to 30 seconds without producing irreversible damage.[26] Moveable tissue is more vulnerable. From this, the researchers concluded that up to 90 psi was acceptable on undamaged oral tissue while 50 to 70 psi was recommended for inflamed or ulcerated tissue.[26] Selting et al found that efficacy was similar between medium and high pressure settings, but at lower settings it was 50% less efficient.[27]

Depth of Delivery

Water (or other solutions) delivered by a dental water jet create the process of subgingival irrigation. Water contacting with the embrasure area creates 2 zones of hydrokinetic activity. One is the impact zone, where the solution makes initial contact in the mouth. The second is the flushing zone, where the water widens out in concentric circles penetrating subgingivally.[29]

The most common tip used on a dental water jet is the standard jet tip (Figure 1). Studies have found that using the jet tip results in penetration of approximately 50% of the pocket depth. Depth of penetration may differ depending upon pocket depth and tip placement (Table 1).[30,31] There are a variety of subgingival tips available, but only one soft, conical, latex–free tip (Pik Pocket™ Subgingival Irrigation Tip, Water Pik, Inc, Fort Collins,

Table 1: Depth of Penetration with a Standard Jet[30]

Tip Placement	90 degree application		45 degree application	
Pocket Depth	Mean Percent Pocket Penetration	Incidence of 75% Pocket Penetration	Mean Percent Pocket Penetration	Incidence of 75% Pocket Penetration
0– 3 mm	71%	42.9%	54%	30.8%
4–7 mm	44%	25%	46%	29.9%
>7 mm	68%	60%	58%	34.4%

Colo.) has been scientifically evaluated (Figure 2). In pockets up to 6 mm in depth, penetration was 90% of pocket depth. In pockets 7 mm or greater, penetration was 64%. In comparison, rinsing penetrated 21% of the pocket depth.[32]

Solutions

Practitioners often view the dental water jet as a delivery device for antimicrobial solutions. Because the bulk of the research supports efficacy with plain water, it is more likely that efficacy is related to the mechanism of action versus the type of agent used. Adding an antimicrobial agent does have the potential to increase efficacy.[8–12,14,15,17,21] Flemmig et al compared manual tooth brushing plus either a dental water jet with 0.06% chlorhexidine or a dental water jet with water or 0.12% chlorhexidine rinsing (all used once daily) to tooth brushing alone. The results showed that the dental water jet with chlorhexidine provided the best results for reducing plaque, bleeding and gingivitis. However, the dental water jet with water was better than chlorhexidine rinsing at reducing marginal bleeding (39.6% versus 26.4%) and bleeding on probing (24% versus 15%).[10]

Clinical Measures

One of the earliest studies on the dental water jet, conducted in 1969, found it had the ability to significantly reduce calculus and gingivitis (50% and 52%, respectively) without causing injury in uninstructed users.[3] Over the years, numerous studies confirmed that the dental water jet provided significant benefits in the reduction of bleeding and gingivitis[1,2,4–23] (Table 2).

Figure 1: Subgingival penetration with a standard jet tip

Figure 2: Subgingival delivery with a soft, site specific subgingival tip

Early work looked at plaque removal and focused on the dental water jet as a monotherapy rather than an adjunct to tooth brushing. These studies found a limited effect on supragingival plaque.[33,34] In contrast, numerous studies that have utilized methodologies with the dental water jet as an adjunct to tooth brushing sometimes found significant reductions in plaque.[1,6,19,20,22] At minimum, the data often showed plaque reductions from baseline, though not necessarily better than tooth brushing alone.[3,4,10,13]

A 2009 study conducted by Gorur et al demonstrated that a dental water jet removes plaque biofilm. A total of 8 extracted teeth from a subject with advanced aggressive periodontitis were sliced and treated with ex–vivo salivary biofilm or served as untreated controls. Of those, 4 slices were treated for 3 seconds with the standard jet tip and 4 with the orthodontic tip. The unit was on a medium pressure setting (70 psi). When examined under the scanning electron microscope, it was shown that both the jet tip and orthodontic tip removed extensive biofilm, 99.9% and 99.8%, respectively, compared to untreated specimens. Biofilm removal was observed at both the crown surface and below the cemento–enamel junction.[35]

Infection

The primary physical action from a dental water jet has been shown to occur subgingivally.[8,9,11,14,15,30–33,36–38] Cobb et al compared test specimens from irrigated and non–irrigated extracted teeth that received no dental instrumentation for a minimum of 6 months. Upon examination with a scanning electron microscope, irrigated areas exhibited fewer microorganisms than the test groups in zones up to 6 mm. Additionally, non–irrigated areas contained plaque meshed in a fibrin–like material, whereas in irrigated specimens there was none or only a light fibrin–like network present.[26] Other researchers have also found bacterial reductions,[8,11,14,15,27,28] with Drisko et al showing the dental water jet disrupted spirochetes up to 6 mm.[27] Chaves et al found that the dental water jet with either water

or 0.04% chlorhexidine reduced subgingival pathogens, while 0.12% chlorhexidine rinsing or tooth brushing alone could not.[15]

Inflammation

Multiple studies have observed that adding a dental water jet to tooth brushing increases the reduction of bleeding and gingivitis over tooth brushing alone.[1–23] Because these improvements were not always accompanied by enhanced plaque reduction, researchers began to speculate that other mechanisms related to inflammation were involved.[11,13,15] In 2000, Cutler et al compared tooth brushing plus a dental water jet (with water only) to tooth brushing alone and found statistically significant improvements in traditional clinical measures as well as evidence of a "host modulation" effect. Samples of gingival crevicular fluid were taken 8 hours post–irrigation and analyzed for the presence of both pro– and anti–inflammatory mediators commonly associated with alveolar bone and attachment loss. The analysis revealed that in as little as 2 weeks, the dental water jet reduced the production of the destructive or pro–inflammatory mediators (IL–1β) while increasing 1 anti–inflammatory agent (IL–10) and stabilizing another known for its bactericidal capabilities (IFN–γ). Further scrutiny revealed that the reduction of bleeding on probing correlated to the reduction of one of the pro–inflammatory mediators, IL–1β, and not plaque reduction. The investigators concluded that the data supports the contention that oral irrigation is of clinical benefit due to a selective modulation of inflammatory mediators.[19] Two years later, a 3 month study on individuals with diabetes found similar host modulation outcomes as measured via blood serum.[20]

Patient–based Outcomes

It is well established that some patients are more susceptible to gingivitis and periodontal disease or have more difficult plaque–removal challenges. The dental water jet has been tested on numerous patient groups. These include those in periodontal maintenance[9,11–14,17,19] or who have orthodontic appliances,[6,16,23,24] implants,[18] crown and bridge,[1] diabetes[20] and non–compliance with flossing[22,23] (Table 3).

Diabetes

In a study of 52 subjects with either type 1 or type 2 diabetes, patients received scaling, root planing and self–care instructions for either routine oral hygiene (brushing and flossing, only if it was already a habit) or routine oral hygiene plus use of a dental water jet with the subgingival tip 2 times a day. At 3 months, the group using the dental water jet had better improvements in both oral and systemic health as measured by traditional clinical indices and serum pro–inflammatory mediator level. This included a 44% better reduction in bleeding, 41% better reduction in gingivitis and significant reductions in IL–1β and PGE2. Both groups had improvements in glycated hemoglobin (HbA1C), although there were no significant differences from

Table 2: Synopsis of Statistically Significant Re

Year	Primary Investigator	Subjects	Length	Agent(s)	Calcul
1969	Lobene[3]	184	12 wks	Water	Yes
1970	Hurst[24]	60	63 days	Water	NE
1971	Hoover[4]	48	3 mos	Water	Yes
1972	Lainson[5]	115	One year post 3 mos study	Water	No
1983	Phelps–Sandall[6]	21	6 wks	Water	NE
1989	Ciancio[8]	66	6 wks	Essential Oil Water	NE
1990	Newman[28]	222	6 mos	0.06% CHX+Water	NE
1990	Jolkovsky[9]	60	3 mos	0.04% CHX Water	NE
1990	Flemmig[10]	222	6 mos	0.06% CHX+Water	No No
1990	Brownstein[11]	44	60 days	0.06% CHX Water	NE
1992	Walsh[12]	16	56 days	0.02% CHX Water	NE
1994	Newman[13]	155	6 mos	Zinc sulphate Water	NE
1994	Fine[14]	50	6 wks	Essential Oil Water	NE
1994	Chaves[15]	125	6 mos	0.04% CHX Water	NE
1994	Burch[16]	47	2 mos	Water	NE
1995	Flemmig[17]	60	6 mos	Buffered 0.3% ASA++Water	NE
1997	Felo[18]	24	3 mos	0.12% CHX	Yes
2000	Cutler[19]	52	28 days	Water	NE
2002	Al–Mubarak[20]	52	3 mos	Water	NE
2003	Pistorius[21]	89	12 wks	Herbal§ CPC±	NE
2005	Barnes[22]	105	28 days	Water	NE
2007	Sharma[23]	105	28 days	Water	NE

*NE = Not evaluated in the study

+Chlorhexidine

++Acetylsalicylic acid

§ Herbal rinse contained: salvia officinalis, metha piperita, menthol, matrica Echinacea purpurea diluted: 2.5 parts to 100 parts water

± Contains sodium benzoate, poloxamer 338, cetylpyridium chloride, and sodiu

ductions in Clinical Outcomes: 1969–2007

us	Plaque (Biofilm)	Gingivitis	Bleeding	Probing Depth	Bacteria	Inflammatory Mediators
	No	Yes	NE*	NE	NE	NE
	NE	NE	NE	NE	Yes	NE
	Yes	Yes	NE	NE	NE	NE
	NE	Yes	NE	No	NE	NE
	Yes	Yes	NE	NE	NE	NE
	Yes No	Yes Yes	Yes No	No No	Yes No	NE
	NE	NE	NE	NE	Yes No	NE
	Yes Yes	Yes Yes	NE	Yes Yes	Yes No	NE
	Yes No	Yes Yes	Yes Yes	Yes No	NE	NE
	Yes No	Yes No	Yes No	NE	Yes No	NE
	Yes No	NE	Yes No	Yes Yes	NE	NE
	No No	No Yes	Yes Yes	No Yes	NE	NE
	Yes No	Yes No	Yes No	No No	Yes Yes	NE
	Yes No	No No	Yes Yes	NE	Yes Yes	NE
	Yes	Yes	Yes	No	NE	NE
	No No	Yes Yes	No Yes	Yes Yes	NE	NE
	Yes	Yes	Yes	NE	NE	NE
	Yes	Yes	Yes	Yes	NE	Yes
	Yes	Yes	Yes	NE	NE	Yes
	No No	Yes Yes	Yes No	No No	NE	NE
	Yes	Yes	Yes	NE	NE	NE
	Yes	NE	Yes	NE	NE	NE

ia chamolilla, commiphora myrrha, carvum carvi, Eugenia caryophyllus, and

n fluoride diluted 2.5 parts to 100 parts water

baseline or between the groups.[20]

Implant/Crown and Bridge

The dental water jet with a subgingival tip used at low pressure has been tested on patients with implants and found safe and effective. Twenty–four subjects used either a dental water jet with half strength chlorhexidine (0.06%) or a full strength (0.12%) chlorhexidine rinse once daily. The group using the dental water jet had statistically greater reductions than the rinsing group for plaque, gingivitis and stain. The authors concluded a dental water jet is safe and effective for use on implants. They also speculated that irrigation was more effective than rinsing because irrigation allowed the chlorhexidine to penetrate deeper into the pocket, creating substantivity with the epithelium.[18]

In an early study that used a split mouth design, subjects undergoing periodontal therapy added a dental water jet to tooth brushing on the left side of the mouth only. When the sides were compared, the findings showed that using the dental water jet increased plaque removal and reduced gingivitis. The investigators also found that the subjects who had the best results had either fixed bridgework or crowns.[1]

Orthodontic Appliances

Multiple studies have evaluated the impact of a dental water jet on orthodontic appliances.[6,16,23,24] An early study by Hurst and Macedonia found that the addition of a dental water jet to tooth brushing was 80% more effective than tooth brushing and rinsing in reducing the total aerobic flora and 60% more effective in reducing the lactobacillus count in orthodontic patients.[24] A 2 month study by Burch et al found that adult orthodontic patients who added the dental water jet to either manual or a powered toothbrush had greater reductions in plaque, bleeding and gingivitis versus brushing alone.[16] A recent study of 105 adolescents ranging in age from 11 to 17 years compared a dental water jet with a tip designed specifically for orthodontic appliances plus manual tooth brushing to both manual tooth brushing plus floss via a floss threader and manual tooth brushing alone (Figure 3). The addition of the dental water jet and orthodontic tip (with water) was significantly more effective at plaque removal than brushing plus flossing with a floss threader or brushing alone, 3.76 and 5.83, respectively. The dental water jet also provided a significantly better reduction in bleeding – 84.5% from baseline. This was 26% better than the results achieved with dental floss.[23] Phelps–Sandall and Oxford evaluated the use of a dental water jet and sulcus brush on patients in maxillary fixation and found that using a dental water jet resulted in more plaque removal, less inflammation and less trauma.[6]

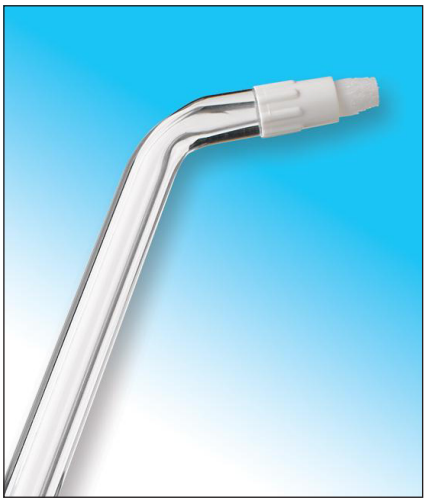
Periodontal maintenance

Newman et al conducted a 6 month, multi–center study with 155 subjects who had been treated for periodontal disease. All had at least 2 to 5 mm pockets with bleeding upon probing. The subjects who added a dental water jet (with water) to their daily routine had

Table 3: Patient Outcomes

Condition	Investigator/Year
Crown & Bridge[1]	Krajewski, 1964
Diabetes[20]	Al–Mubarak, 2002
Implants[18]	Felo, 1997
Orthodontic Appliances including Maxillary Fixation[6,16,23,24]	Hurst, 1970 Phelps–Sandall, 1983 Burch, 1994 Sharma, 2008
Periodontal Maintenance[9,11–14,17,19]	Brownstein, 1990 Jolkovsky, 1990 Walsh, 1992 Fine, 1994 Newman, 1994 Flemmig,1995 Cutler, 2000

Figure 3: Specialized orthodontic tip



significantly greater reductions in gingival inflammation, bleeding on probing and probing depth reduction as compared to the other groups.[13] Flemmig et al demonstrated similar reductions for gingivitis, bleeding on probing and probing depth in a group of 60 subjects in supportive periodontal therapy.[17] Likewise, studies that have employed scaling and root planing followed by use of a dental water jet with the subgingival tip have also found greater reductions in inflammation.[9,14]

Floss Alternative

A 28 day clinical trial with 105 subjects was conducted by Barnes et al to determine which oral health care routine was most effective: manual toothbrush and floss, manual toothbrush and a dental water jet or sonic powered toothbrush and a dental water jet. The results showed that, when combined with either a manual or a sonic toothbrush, the dental water jet was is as effective as a manual toothbrush and floss at removing plaque and significantly better at reducing bleeding and gingivitis. The group using the manual brush and dental water jet was nearly twice as effective at reducing bleeding as the manual brush and floss.[22] Likewise, Sharma et al found that adding a dental water jet with an orthodontic tip to manual brushing was more effective than the addition of floss with a floss threader or brushing alone for removing plaque and reducing bleeding.[23]

Safety

Tissue appearance

Krejewski et al obtained biopsied specimens from patients using a dental water jet. The specimens were microscopically evaluated and the irrigated tissue was found to have less inflammation, better connective tissue organization and greater keratin layer thickness in irrigated tissue compared to non–irrigated areas.[1] In 1970, Cantor found a decrease in inflammation in central col depressions following the use of a dental water jet, but no increase in keratinization.[2] In 1988, Cobb et al compared irrigated and non–irrigated tissue under a scanning electron microscope and found no observable differences in relationship to epithelial topography, cavitations, microulcerations, spatial relationships and individual cell appearance.[36]

Bacteria

In 1970, O'Leary et al used stained carbon particles in water in 3 different types of dental water jets and found penetration into epithelial tissue regardless of the type of unit or pressure used.[39] In 1978, Manhold conducted a similar experiment and also found some penetration by carbon particles after the use of a dental water jet. However, the investigators also found carbon penetration in areas that had not been irrigated, and noted that overall, any penetration in areas, irrigated or not, seemed random. They concluded that definitive conclusions were not possible, and the issue was likely more academic than practical.[40] Since that time, numerous studies have evaluated the subgingival bacteria population and consistently found reductions.[8,9,14,15,24,36–38]

Bacteremia

Most dental procedures and self–care devices are capable of causing a bacteremia, including the use of a dental water jet.[41–44] The bacteremia produced by a dental water jet is similar to tooth brushing and flossing (20% to 68%), wooden toothpicks (20% to 40%) and mastication (7% to 51%).[41] Bacteremia resulting from the use of a dental water jet has been shown to range from 7% for those with gingivitis to 50% for those with periodontal disease.[42,43] In a population of people with healthy tissue, those using a dental water jet had a bacteremia rate of 27%.[44] Both medium and maximum settings were used, and the difference in levels did not influence the rate of bacteremia. In contrast, Tamimi et al found no evi-

dence of bacteremia following the use of dental water jet in a group of subjects whose oral health status ranged from healthy gingiva to periodontal disease.[45]

Discussion

The dental water jet has been evaluated numerous times over the last 45 years. Clinical trials began in the late 1960s and continue today. The bulk were conducted from the mid 1980s through the late 1990s and produced a solid body of evidence demonstrating its safety and effectiveness at reducing gingivitis and bleeding.[8–18,30–32,36–38] More recent work, from 2000 onward, has focused on plaque biofilm removal[35] and benefits for specific patient needs, such as orthodontic appliances,[23] diabetes[20] and non–compliant flossers.[22,23]

While the results for bleeding and gingivitis reduction have been consistent over the years, findings regarding plaque biofilm removal have been mixed.[1,3,4,6,10,13,19,20,22,33,34] One early study that looked at plaque and concluded that the dental water jet "did not fulfill the requirement of an effective plaque control device" actually found that the dental water jet as a monotherapy did significantly reduce plaque and gingivitis over no oral hygiene. The reductions were greatest interproximally. However, the dental water jet did not enhance plaque removal when added to tooth brushing.[33] Several studies concur with this result.[3,4,10,13] More recent studies did find either enhanced plaque removal with the dental water jet when added to tooth brushing or equivalent removal compared to dental floss.[19,20,22] A 2009 laboratory study that used scanning electron microscopy found that teeth treated with a 3 second pulsating lavage had 99% plaque biofilm removal.[35]

Future research endeavors need to be undertaken to provide clarity on the issue of plaque biofilm removal. Emerging findings on biofilm may produce new evaluation tools as well as philosophies about the necessity of complete plaque biofilm removal. Another area of research that would merit from additional studies is the dental water jet as an effective alternative to flossing. Due to low rates of flossing, clinicians are in need of products they can confidently recommend as an evidence–based alternative. Given that the product already does have a large body of evidence, a systematic review would be beneficial to the clinician.

Disclosure: Carol Jahn is full time employee of Water Pik, Inc currently as the Senior Professional Relations Manager.

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