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The effectiveness of a magnetized water oral irrigator (Hydro Floss®) on plaque, calculus and gingival health

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Abstract. The purpose of this study was to evaluate the effects of a magnetized water oral irrigator on plaque, calculus and gingival health. 29 patients completed this double-blind crossover study. Each patient was brought to baseline via an oral prophylaxis with a plaque index ≤1 and a gingival index ≤1. Subjects used the irrigator for a period of 3 months with the magnet and 3 months without the magnet. After each 3 month interval, data were collected using the plaque index, gingival index, and accretions index. The repeated measures analysis on plaque, gingival and calculus indices yielded a statistically-significant period effect for PII (p=0.0343), GI (p=0.0091), and approached significance for calculus (p=0.0593). This meant that the effect of irrigation resulted in a decrease of all indices over time. Therefore, the treatment effect on each index was evaluated using only the measurements obtained at the end of the first period (i.e., assuming a parallel design). Irrigation with magnetized water resulted in 64% less calculus compared to the control group. The reduction was statistically significant (p≤0.02). The reduction by 27% in gingival index was not statistically significant. The reduction in plaque was minimal (2.2%). A strong positive correlation between the plaque index and the Watt accretion index was observed. The magnetized water oral irrigator could be a useful adjunct in the prevention of calculus accumulation in periodontal patients, but appears to have minimal effect on plaque reduction. The results indicated a clinical improvement in the gingival index, but this was not a statistically significant finding.

Key words: irrigation; plaque control; magnetized water; calculus

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Plaque is the primary etiologic agent in chronic inflammatory periodontal disease, with calculus a contributing factor. Teeth with calculus have been shown to have a significantly higher rate of loss of attachment than those that remain calculus free (Anerud et al. 1991). Toothbrushing is universally accepted as a standard method to control plaque and calculus formation (Bass 1954). In recent years, oral hygiene standards have improved (Kornman & Löe 1993). However, a need still exists for techniques to significantly decrease plaque and calculus formation.

Studies have shown that oral irrigators can be useful adjuncts in an oral physiotherapy program (Lang & Räber 1981, Lang & Ramseier-Grossmann 1981, Boyd et al. 1985). However, opportunities clearly exist to improve their effectiveness (Derdivanis et al. 1978, Watt et al. 1993). A double-blind study by Watt et al. (1993) showed that magnetically-treated water flowing through an oral irrigator significantly decreased plaque and calculus (combined) by 45%.

Under normal physiologic conditions, the tooth and bacterial surfaces carry a net negative charge. The mediation of attachment for plaque and calculus (Mandel 1963) involves the interaction of bacteria which are negatively charged (Rölla 1977), and amphipatic substances which can change the charge of the tooth resulting in bacterial attachment (Krasse 1977). These interactions, which are normal occurrences, allow for the mineralization of plaque on tooth surfaces. In theory, a magnetized water oral irrigator inhibits the bonding process by which bacteria colonize and by which plaque attaches to teeth. This inhibition is based on the principle of magnetohydrodynamics. Magnetohydrodynamics prevents naturally-occurring mineral deposits in

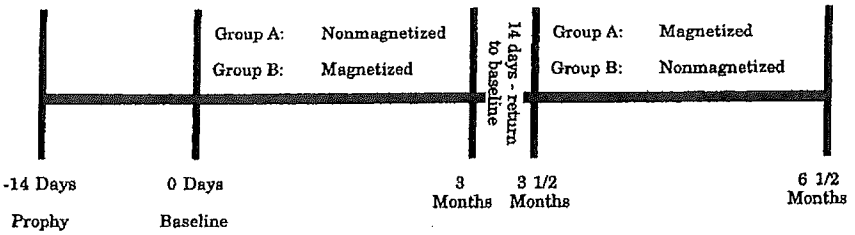

Fig. 1. Experimental design. Beginning at baseline, gingival index, plaque index, accretions index and modified accretions index were recorded at 3 months and 6.5 months. At 3 months, a prophylaxis was performed, followed by a 14-day "wash out" period.

fluids from changing from a liquid to a solid state (Grutsch & McClintock 1984, Hibben 1973). This occurs by interruption of the normal process of ionization (electrovalent bonding of ions), and therefore prevents the formation of deposits which would otherwise adhere to a host surface. By applying this principle to an oral irrigator, the bonding process by which bacteria colonizes, and by which plaque and calculus adheres and accumulates on teeth is inhibited.

The purpose of this study was to evaluate the effects of a magnetized water oral irrigator (*Hydro Floss®) on gingival inflammation, plaque and calculus formation.

Material and Methods

32 patients who presented with supragingival calculus volunteered for this study at the Medical University of South Carolina. Patients met the following criteria to participate.

(1) No systemic conditions contraindicating dental treatment.

(2) No systemic antibiotics during the previous 6 months.

(3) Visible supragingival plaque and calculus present on the buccal and/or lingual of the lower 6 anterior teeth (Kornman & Löe 1993).

(4) Proven calculus producers by documented history.

All patients voluntarily signed an informed consent document approved by the Institutional Review Board for Human Research of the Medical University of South Carolina.

All patients were brought to baseline through supragingival and subgingival scaling and rubber cup polishing, by the principal investigator (KEJ). They began the study (Fig. 1) 2 weeks after the subgingival scaling of the lower anterior teeth, with a Löe & Silness (1963) gingival index of ≤1, and a Turesky plaque index (1970) of ≤1. The patient's gingival condition was scored with the Löe and Silness (1963) gingival index on the facial, lingual, mesial and distal aspects of the mandibular anterior teeth. Anatomical line angles delineated the 4 areas. The areas between the mesio-facial and disto-facial line angles, and the mesio-lingual to disto-lingual line angles were considered the facial and lingual surfaces, respectively. The areas between the mesio-facial and mesio-lingual line angles and the disto-facial and disto-lingual line angles were considered the mesial and distal surfaces, respectively.

Plaque was disclosed with red disclosing solution (Red-Cote#, FDC #3) and the Turesky-Gilmore-Glickman Modification (1970) of the Quigley-Hein plaque index was used. A score of 0 to 5 was assigned to each facial and lingual surface of the lower anterior teeth. This tooth system was used to replicate the system used in the original report by Watt et al. (1993) on the effects of a magnetized water oral irrigator. Though the data was collected blindly by the principal investigator (KEJ), all investigators were initially calibrated to improve reproducibility and to reduce inter and intra examiner differences.

Irrigation units (HydroFloss®) were supplied and coded by the manufacturer. Sixteen units had their magnetic devices removed by the manufacturer during the first phase of the study. In an effort to standardize the water flow of the irrigators, all the low and high settings were disabled by the manufacturer, so that all of the participants were using the medium flow setting. To ensure a double blind clinical trial, neither the examiner nor the patient knew which units had the magnetic devices in them. The units were given to the patients with the following instructions.

(1) Irrigate 2× a day per the manufacturer's instructions: "Hold the jet tip at a right angle, directing the flow of water to the center of the tooth at the gum line for approximately five seconds on the front side of each tooth and 5 s on the back side of each tooth. As you go from tooth to tooth, direct the flow of the water between your teeth long enough to remove debris. For best results, this procedure should be followed 2× daily, once each morning and once each evening."

(2) Use the unit specifically on the lower 6 anterior teeth.

(3) Oral hygiene procedures of the lower 6 anterior teeth will be restricted to manual tooth brushing and the oral irrigator.

No instructions were given on brushing technique or length of brushing. However, the subjects were instructed not to use floss, interdental brushes or mouthrinses in the study areas during the study periods.

After 3 months of oral irrigator use, the indices were recorded again. The accretions index (Watt et al. 1993) evaluated: (1) the height of the accretions from the gingival margin up to 3 mm to the coronal portion of the tooth; (2) the thickness of the accretions on the tooth surface. A periodontal probe was used to measure the thickness of the accretions following the design recommendations of Detsch (1980) to obtain measurements accurate to 0.1 mm. The design of this probe utilizes a 0.021 inch orthodontic wire attached to a Boley Gauge†. The orthodontic wire is housed within a 16 gauge stainless steel catheter with a 1.2 mm internal diameter.

The Watt accretions index was utilized (Fig. 2):

(1) Measurements were taken on the 6 surfaces of each anterior tooth (DF, F, MF, ML, L, and DL). The surfaces were delineated by line angles.

(2) Each of the 6 tooth surfaces were further divided into 3 sections via an apical-incisal delineation. Therefore 18 sections (9 on the facial and 9 on the lingual) were assessed for thickness of accretions. Fig. 2 is the chart for recording one surface. All 18 sections

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John O. Butler Company, Chicago, Illinois 60630, USA.

† Hu-Friedy, Chicago, Ill. 60618, USA.

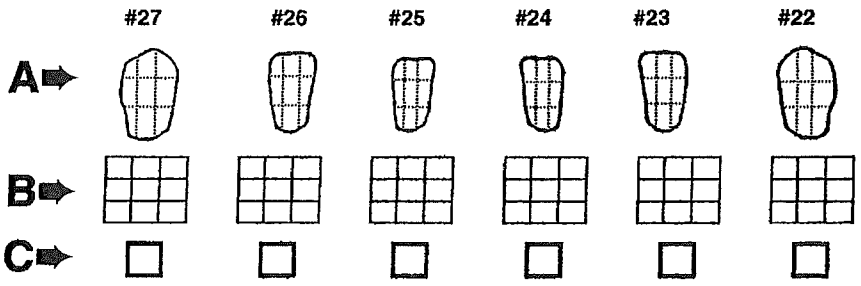

Fig. 2. Accretions charting record. *a.* Each surface (facial and lingual) was divided into 9 sections. *b.* The thickness of accretions in each section was measured using the following scoring: "0"=0.0 mm, "1"=>0.0 to <0.5 mm, "2"=≤0.5 to <1.0 mm, "3"=≥1.0 mm. *c.* The sum of all the socres in part B.

were summed, and thus no data is reported by section.

(3) For each of the 18 sections, a thickness measurement was recorded using the following scoring: "0" (no visible deposit)=0.0 mm, "1"=>0.0 to <0.5 mm, "2"=≥0.5 to <1.0 mm, and "3"=≥1.0 mm.

After this index (measuring plaque and calculus) was scored, a rubber cup polishing was performed to score calculus only (referred to as the modified Watt accretion index). Both the Watt accretions index and the modified Watt accretion index were scored at the 3 month and 6.5 months evaluations.

Gingival, plaque and accretions indices were assessed by the principal investigator (KEJ). After the 1st 3 months of use and assessment completions, a crossover was initiated to have the patients serve as their own controls. The units were returned to the manufacturer to remove the magnetic device from those units that had them in place, and to replace the magnetic devices in those that had them removed. All patients were again brought back to base-line. The units now with the new modifications were re-issued to the patients, with instructions on their use for another three months. Patients were re-examined after the 2nd 3-month period, and the same clinical data collected and assessed by the principal investigator (Fig. 1).

If a unit malfunctioned, the manufacturer was given the code of the unit and the investigator was told which of the remaining units could be issued to the patient in order to ensure that the same type of unit was being used for that clinical period.

Statistical analysis

For each participant, his/her gingival and plaque indices were derived by averaging the respective scores form the surfaces of the 6 lower anterior teeth (#22 through #27). The plaque index used in the analysis was calculated by averaging the scores from the facial and lingual surfaces of the 6 teeth. The gingival index was derived by taking the average of the scores from distal facial, facial, mesial facial, mesial lingual, and distal lingual surfaces from the 6 teeth. The accretion index was based on the nine scores from the subdivided facial surface of the 6 teeth.

The resulting indices were approximately normally distributed. Consequently, standard univariate parametric tests, such as the two-sample *t*-test to compare the mean indices between the magnetized and non-magnetized groups, and the paired *t*-tests to evaluate the differences between facial and lingual or proximal and non-proximal surfaces, were utilized. Analysis of covariance method was used to compare the differences in the mean indices between magnetized and non-magnetized groups adjusting for age and sex. The Pearson correlation coefficients were calculated to evaluate the degree of association between the plaque and accretion indices.

Results

Of the 32 patients who enrolled in this study, 29 completed both periods of the double blind, two-period crossover clinical trial. One patient voluntarily left after the first visit, one moved to another country, and one was hospitalized for an unrelated ailment. During the study, 4 units had to be reissued by the manufacturer. Two were accidentally dropped by patients and two lost/delayed in the mail during the crossover periods.

Since all the patients' teeth were cleaned prior to each of the 2 periods such that the average scores of their plaque, gingival and calculus indices were zero, no clinical carryover effect is assumed. The repeated measures analysis on plaque, gingival and calculus indices yielded a statistically significant period effect for PlI (p=0.0343), GI (p=0.0091), and approached significance for calculus (p=0.0593). This meant that an overall reduction in the indices occurring over the 2 trial periods was not necessarily due to the treatment (magnetized) but possibly to the fact that water oral irrigation was used, or a placebo effect due to participation in a study itself. Therefore, the treatment effect on each of the indices (unadjusted and adjusted for age and sex) was evaluated using only the measures taken at examination 3 at the end of the first period, hence assuming a parallel design. The results of the analyses are given in Table 1.

The treatment with the magnetized water yielded a significantly lower calculus index (64%) during the first period, even after adjusting for age and sex. Gingival inflammation was reduced by 27.5%, which was not statistically significant. There was no significant reduction in plaque index (2.2%). Post-

Table 1. Indices at 3 months

Index	Group[a]	Mean	SE	p (unadj.)	p (adj.)[b]
Plaque (Turesky)	A	1.80	0.22	0.8865	0.9128
	B	1.76	0.22		
Gingival (Löe & Silness)	A	0.80	0.09	0.1130	0.0655
	B	0.58	0.10		
Calculus (modified Watt's)	A	0.42	0.09	0.0087	0.0172
	B	0.15	0.03		

[a] Group A (n=16) used non-magnetized water from baseline to 3 months and group B (n=13) used magnetized water.

[b] Adjusting for age and sex.

Table 2. The Pearson correlation coefficient between the Turesky plaque index and the Watt accretion (plaque and calculus) index (n=29)

Surface	Period 1	Period 2
facial	*0.66	*0.85
lingual	*0.69	*0.69

* $p<0.0001$.

analysis power calculations show that the t-tests which yielded the non-significant results had power of 95% to detect a 45% difference in the plaque index and a power of 97% to detect a 45% difference in the gingival index, between the treated and placebo groups.

The Pearson correlation coefficients between the Turesky plaque index and Watt accretion (plaque & calculus) Index are listed in Table 2 by surface (facial and lingual) and by treatment period. These coefficients were significantly different from zero ($p<0.0001$). Therefore, the Watt accretion index showed a strong positive association with the Turesky's plaque index.

Table 3 provides the results from the analyses of the Turesky plaque index comparing the facial and lingual surfaces. Regardless of treatment or period, lingual surfaces had statistically significantly higher plaque indices than facial surfaces. Difference in plaque index was affected more by period, rather than treatment.

Table 4 compares the results for gingival index between interproximal and nonproximal surfaces. The interproximal surfaces had higher gingival indices than the non-proximal surfaces. The difference in gingival index between interproximal and nonproximal surfaces was statistically significant regardless of treatment or period.

Discussion

The use of a magnetized water oral irrigator showed 64% less calculus formation in the test group than the control group, which was a statistically significant finding. Although the gingival index was 27% lower with the group using the magnetized water, this was not statistically significant. There was not a statistically significant difference for plaque index (PII 2.2%). Our findings are consistent with studies that examined supragingival irrigation. Numerous authors have found that gingival inflammation either persisted or developed with supragingival irrigation (Lang & Räber 1981, Lang & Ramseier-Grossmann 1981,Hugoson 1978, Lobene et al. 1972, Southard et al. 1987). Similarly, no difference in plaque accumulation between the control and treated groups with supragingival irrigation was noted by Derdivanis et al. (1978). Based on the theory of hydromagnetics it is not a surprising finding that the irrigator had minimal effect on plaque accumulation, but a statistically significant effect on calculus formation. Calculus is mineralized plaque that forms by the bathing of the plaque in a supersaturated solution of Ca^{++} and PO_4-saliva. The magnetized water irrigator simply prevents or inhibits the process of this mineralization from occurring. Therefore, it appears that plaque continues to be produced at its normal rate in the individual patient, but the mineralization process is interrupted. This principle of hydromagnetics, first described by Faraday in 1832, has been used successfully in industry for years to reduce lime and scale deposits adherence to pipes (Grutsch & McClintock 1984).

Criticisms of the study by Watt et al. (1993) included the fact that the investigators did not: (1) attempt to standardize the water flow through the irrigator, (2) demonstrate that their experimental and control groups were matched in deposit forming capabilities, (3) separate plaque from calculus in their assessments. Furthermore, an assessment of clinical effectiveness was not a part of their experimental design, nor were the indices used standard in the literature for obtaining these measurements. The original design of our study attempted to address these concerns by having patients serve as their own controls via a crossover design, collecting data with traditional periodontal indices, and incorporating the Watt accretions index. The Turesky-Gilmore-Glickman modification (1970) of the Quigley-Hein plaque index used in this study has been used in many clinical trials documented in the literature, and was selected due to its capability of measuring plaque over the entire tooth surface. The Watt accretion index in spite of the criticism of it not being a traditional periodontal index, showed a strong positive association with the Turesky plaque index. This was probably due to the fact that both indices assess plaque starting at the gingival margin, progressing coronally on the tooth surface.

For each participant, gingival, plaque and accretion indices for the entire mouth were determined by averaging the respective scores from the surfaces measured on the 6 teeth. The plaque index analyzed was calculated from taking the average scores from the facial and lingual surfaces of the lower anterior teeth (#22–27) of each participant. Similarly, the gingival index for each participant was derived from averaging the scores from distal facial (DF), facial (F), mesial facial (MF), mesial lingual (ML), lingual (L), and distal lingual (DL) surfaces of the lower anterior teeth (#22–27). The accretion index was based on 18 scores from the subdivided facial and lingual

Table 3. Turesky plaque index: mean difference between facial and lingual surfaces

Group	Period	Mean	SE	p*
A	1 (non-magnetized)	−0.33	0.32	0.3128
A	2 (magnetized)	−0.52	0.16	0.0057
B	1 (magnetized)	−0.05	0.29	0.8615
B	2 (non-magnetized)	−0.52	0.22	0.0331

* p-value for the paired t-test to test the significance of the difference between facial and lingual plaque index.

Table 4. Gingival index (GI): mean difference between non-proximal and interproximal surfaces

Group	Period	Mean	SE	p*
A	1 (non-magnetized)	−0.09	0.04	0.0390**
A	2 (magnetized)	−0.07	0.03	0.0560
B	1 (magnetized)	−0.11	0.05	0.0398**
B	2 (non-magnetized)	−0.09	0.03	0.0124**

* p-value for the paired t-test to test the significance of the difference between interproximal and nonproximal gingival index.

** statistically significant $p<0.05$.

surfaces of these teeth (Fig. 2) The resulting indices were mostly normally distributed. Consequently, parametric tests, such as the two-sample *t*-test to compare the mean indices between the magnetized and non-magnetized groups, and paired *t*-test to evaluate differences between facial and lingual or proximal and non-proximal surfaces, were applied. ANOVA was used to compare the differences in the mean indices between the two groups adjusting for age and sex. Furthermore, the Pearson correlation coefficient used was an appropriate measure of association between the Turesky plaque index and Watt accretion index, given that they were interval-scaled variables. Due to the period effect observed, and the assumption of a parallel design, however, the criticism regarding the matching of calculus formation of the subjects remained a problem in our study.

Unlike the previous study by Watt et al. (1993), in which 13% of the patients dropped out due to units malfunctioning, none of the units malfunctioned in our study. None of the study participants dropped out due to the study. One participant exited immediately after the initial appointment, anticipating time constraints, one moved to another country, and the other was hospitalized for an unrelated problem.

It was interesting to note that the older participants stated that they liked the units and actually missed them during the 14-day washout period, whereas the younger subjects were not as enthusiastic. 40% of the younger subjects stated that they did not like the noise level of the units.

The principal investigator (KEJ) felt that the calculus was somewhat softer after using the irrigator. While this may not be a direct result of the hydromagnetic effect, it is a possibility. It would be interesting to examine the use of this irrigator with an antimicrobial rinse such as chlorhexidine which is known to produce an increase in calculus formation (Mandel 1988), to determine if this increase could be prevented. Lang & Räber (1981) documented the use of chlorhexidine in an irrigator to be more effective for the application of chlorhexidine than rinsing.

Water irrigation has been shown to reduce gingivitis as well as rinsing with an antimicrobial agent, but not disclosable plaque (Boyd et al. 1985, Lang & Räber 1981, Lang & Ramseier-Grossmann 1981, Flint et al. 1988). Supragingival irrigation when combined with tooth brushing, as in our study, may be of particular benefit for patients who do not or cannot perform adequate interproximal oral hygiene (Lang & Räber 1981, Lang & Ramseier-Grossmann 1981, Hugoson 1978, Aziz-Gandour & Newman 1986, Gupta et al. 1973, Phelps-Sandall & Oxford 1983, Attarzadeh 1981). However, in our study, a statistically significant reduction in gingival index was found in relation to the nonproximal surfaces as compared to the interproximal surfaces regardless of treatment or period (Table 4). Of further research interest would be evaluating the magnetized oral irrigator's effect on interproximal hygiene, to determine if this unit can in fact replace the need for flossing.

As demonstrated by our results, oral irrigation with a magnetized oral irrigator appears to have a beneficial effect in the periodontal management of patients in supportive periodontal therapy by significantly reducing calculus accumulation. (Mandel & Gaffar 1986, Addy & Koltai 1994).

Acknowledgements

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Zusammenfassung

Die Wirksamkeit eines magnetisierten, für die Mundhöhle vorgesehenen Wasserirrigators (Hydro Floss®) auf den Plaque, den Zahnstein und die Gesundheit der Gingiva

Mit der vorliegenden Studie wurde beabsichtigt, die Wirkung eines, für die Mundhöhle vorgesehenen, magnetisierten Wasserirrigators auf Plaque, Zahnstein und Gesundheit der Gingiva auszuwerten. 29 Patienten nahmen an diesem doppelblinden Überkreuzversuch vom Anfang bis zum Ende teil. Mittels Prophylaxebehandlung der Mundhöhle wurde für jeden Patienten die Eingangssituation der Studie durch Erreichen eines Plaqueindex von ≤1 geschaffen. Die Versuchspersonen benutzten den Irrigator 3 Monate lang mit dem Magneten und 3 Monate ohne ihn. Nach jedem der 3 Monate langen Intervalle wurden die Plaque Index-, Gingivalindex- und Anlagerungs-Indexdaten (Accretions Index), zusammengestellt. Die wiederholte Analyse der Messungen der Plaqueindizes, der gingivalen- und Zahnsteinindizes zeigte für den PII einen statistisch abgesicherten (p=0.0343) Periodeneffekt, für den GI von p=0.0091. Für Zahnsteinanlagerungen näherte sich dieser Effekt einer Signifikanz (p=0.0593). Das bedeutete, daß der Irrigationseffekt im Laufe der Studie den Rückgang aller Indizes erreichte. Darum wurde der Behandlungseffekt für jeden Index nur für die am Ende der ersten Periode erhaltenen Messungen evaluiert (d.h. es wurde eine Parallelanlage angenommen). Im Vergleich zu der Kontrollgruppe verringerte die Irrigationsbehandlung mit magnetisiertem Wasser die Zahnsteinanlagerung um 64%. Diese Reduktion war statistisch abgesichert (p≤0.02). Der Rückgang des Gingivalindex um 27% war statistisch nicht signifikant. Die Plaquereduktion war minimal (2.2%). Zwischen dem Plaqueindex und dem Anlagerungs-Index wurde stark positive Korrelation beobachtet. Der für die Mundhöhle vorgesehene Irrigator mit magnetisiertem Wasser könnte als eine brauchbares Adjuvans zur Vorbeugung von Zahnsteinanlagerung bei parodontal erkrankten Patienten gelten. Seine Wirkung auf die Reduktion des Plaque scheint allerdings nur minimal zu sein. Die Ergebnisse ließen eine, jedoch statistisch nicht abgesicherte, klinische Verbesserung des Gingivalindex erkennen.

Résumé

Efficacité d'un irriagateur buccal à eau magnétisée (HydroFloss®) sur la plaque dentaire, le tartre et la santé gingivale

29 patients ont participé à cette étude croisée en double aveugle. Chaque patient a été rendu parodontalement sain via une prophylaxie buccale; indice de plaque ≤1 et indice gingival ≤1. Les sujets ont ensuite utilisé l'irrigateur durant 3 mois soit avec l'aimant soit sans. Après chaque intervalle de 3 mois les données ont été prises en utilisant l'indice de plaque, l'indice gingival et l'indice d'accumulation. L'analyse des mesures répétées sur la plaque dentaire, la gencive et le tartre a mis en évidence un effet significatif pour l'indice de plaque (p=0.0343) et pour l'indice gingival (p=0.0091), et qui approchait la signification pour le tartre (p=0.0593). L'irrigation entraînait donc une diminution de tous les indices. C'est pourquoi l'efficacité du traitement sur chaque indice a été évaluée en utilisant seulement les mesures obtenues à la fin de la première période c'est-à-dire comme s'il y avait un modèle parallèle. L'irrigation avec l'eau magnétiśe a engendré une diminution de 64% du tartre comparé au groupe contrôle. La réduction était significative (p≤0.02). La réduction de 27% de l'indice gingival n'était pas significative. La réduction de la plaque dentaire était minime (2.2%). Une relation positive importante entre l'indice de plaque et l'indice d'accumulation a été observée. L'irrigateur buccal à eau magnétisée pourrait être utile dans la prévention de l'accumulation de tartre chez les patients soignés pour parodontite bien qu'il ne semble avoir

aucun effet sur la plaque dentaire et très peu sur la santé gingivale.

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