A Comparison of Dental Ultrasonic Technologies on Subgingival Calculus Removal: A Pilot Study

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Abstract

Purpose: This pilot study compared the clinical endpoints of the magnetostrictive and piezoelectric ultrasonic instruments on calculus removal. The null hypothesis stated that there is no statistically significant difference in calculus removal between the 2 instruments.

Methods: A quasi–experimental pre– and post–test design was used. Eighteen participants were included. The magnetostrictive and piezoelectric ultrasonic instruments were used in 2 assigned contra–lateral quadrants on each participant. A data collector, blind to treatment assignment, assessed the calculus on 6 predetermined tooth sites before and after ultrasonic instrumentation. Calculus size was evaluated using ordinal measurements on a 4 point scale (0, 1, 2, 3). Subjects were required to have size 2 or 3 calculus deposit on the 6 predetermined sites. One clinician instrumented the pre–assigned quadrants. A maximum time of 20 minutes of instrumentation was allowed with each technology. Immediately after instrumentation, the data collector then conducted the post–test calculus evaluation.

Results: The repeated analysis of variance (ANOVA) was used to analyze the pre– and post–test calculus data ($p \leq 0.05$). The null hypothesis was accepted indicating that there is no statistically significant difference in calculus removal when comparing technologies ($p \leq 0.05$). Therefore, under similar conditions, both technologies removed the same amount of calculus.

Conclusion: This research design could be used as a foundation for continued research in this field. Future studies include implementing this study design with a larger sample size and/or modifying the study design to include multiple clinicians who are data collectors. Also, deposit removal with periodontal maintenance patients could be explored.

Keywords: Ultrasonic instrumentation, calculus removal, piezoelectric, magnetostrictive

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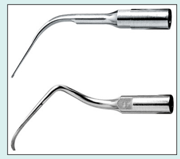
Introduction

More than 80% of the adult population has some form of periodontal disease. In fact, 90% of the 55 to 64 age group has moderate periodontal disease.[1] To date, there are a number of different treatment modalities in the treatment and prevention of periodontal diseases. Conventional treatment for the removal of calculus and plaque biofilm from the root surfaces includes the use of hand–activated instruments such as files, curettes and sickles.[2–4] In the early 1990s, a paradigm shift occurred and ultrasonic instrumentation was the first choice in periodontal instrumentation and became a standard and accepted therapeutic modality.[5–9] There are limited in vivo studies that compare the clinical and therapeutic outcomes of ultrasonic and hand–activated instrumentation, as well as the effects on root surfaces.[2,10–12] However, there is no literature that directly compares the clinical endpoint (immediately post therapy), such as the removal of plaque biofilm, calculus and endotoxin on the root surfaces as well as the root surface characteristics of the magnetostrictive and piezoelectric ultrasonic technologies. As a result, dental health professionals often discuss the differences between the 2 ultrasonic technologies and surmise that one ultrasonic technology is more effective than the other. Some practicing clinicians understand that each instrument works somewhat differently and, thus, these differences may account for anticipated dissimilarities in clinical and therapeutic outcomes. However, these discussions and claims seem to be anecdotal in nature.

There are 2 methods of ultrasonic instrumentation: magnetostrictive and piezoelectric technologies. Each technology has similarities and differences, especially in relation to tip adaptation.

Table I: A Comparison of Ultrasonic Dental Units

Type of Unit	Mechanism of Action	Frequency Cycles/second	Motion of Tip	Tip Samples
Magnetostrictive	Change in electromagnetic field in the ferromagnetic rod causes rapid vibrations	25,000 to 42,000 Hz	Elliptical or Orbital	 Image courtesy of Dentsply
Piezoelectric	Alternating electrical currents applied to the crystal transducer creates a dimensional change that causes rapid vibrations	25,000 to 50,000 Hz	Linear	 Image courtesy of Hu–Friedy Mfg. Co., Inc.
Sonic Instrument	Vibrations are generated by air–turbine from dental unit.	3,000 to 8,000 Hz	Elliptical or Orbital	 Image courtesy of DentalEz

The piezoelectric technology works by adapting 1 of the 2 sides of the tip, whereas any side of the magnetostrictive insert (tip) can be adapted. The piezoelectric tip moves in a linear fashion and the magnetostrictive moves in an elliptical motion (Table I). These differences raise the question of whether tip motion and adaptation would effect calculus removal. The literature reveals that hand–activated, sonic, magnetostrictive and piezoelectric instrumentation provide similar therapeutic results over time as evaluated by measuring bleeding, probing depth, calculus and endotoxin removal.[4]

To date, there is no literature that directly compares the clinical endpoint (e.g. removal of plaque biofilm, calculus and endotoxin from root surfaces) when using the magnetostrictive and piezoelectric ultrasonic instruments. A review of the literature found in vitro studies that compared the 2 technologies using extracted teeth.[3,13,14] In vivo studies that specifically compare both methods of ultrasonic instrumentation are nonexistent. Therefore, clinical evidence is lacking which may lead to the assumption by oral health clinicians that one technology is more effective than the other. If one technology was to be more effective in removing plaque biofilm and calculus, is it possible then that the technology that removes more deposits could result in improved therapeutic outcomes? Therefore, the null hypothesis for this study stated that there is no statistically significant difference in calculus removal between the 2 ultrasonic technologies.

Review of the Literature

Conventional methods for the treatment of periodontal disease include sonic, ultrasonic and hand–activated instrumentation.[4] In the treatment of periodontal diseases, different methods of instrumentation are implemented for maximum healing and restoration of periodontal health. Methods include debridement, scaling and/or root planing and the addition of antibiotics delivered locally or systemically.[15–17] Research studies have investigated the use of ultrasonic and hand–activated instrumentation for the removal of deposits to restore periodontal health.[10,14,18–21]

Ultrasonic instruments were first introduced in dentistry in the early 1950s for the purpose of cutting teeth.[22] In the 1960s, McCall et al reported ultrasonic instrumentation as an acceptable method for plaque biofilm and calculus removal.[23] The main objective for the dental hygiene clinician is to prepare the root surface and promote healing over time as evaluated by therapeutic outcomes during non–surgical periodontal therapy and periodontal maintenance procedures.[13]

Mechanism of Action: Lea et al conducted a study evaluating the Dentsply Cavitron (Dentsply International, York, PA) (a magnetostrictive ultrasonic) and the EMS piezoelectric scaler.[24] The TFI–3 and TFI–10 (Through Flow Insert) ultrasonic tips were used with the cavitron, and the P–10 tip for the piezoelectric. The authors concluded that all generators and tips exhibited differences in amplitude (tip movement). The dental hygiene clinician must understand that although ultrasonic instruments are somewhat similar in operation, they are not exactly equal in relation to power and frequency, and the main difference between the 2 technologies is the working sides of the tips.

The frequency, or speed, refers to the number of times the tip completes an elliptical or linear cycle per second. A frequency of 35,000 Hz (35 kHz) equates to movement of the tip 35,000 cycles in 1 second. The amplitude, or power, controls the length of the stroke of the tip but maintains the same frequency. The higher the power, the longer the stroke and the more powerful the impact on the calculus.[25] In fact, clinical power is the ability to remove deposits in relation to the stroke, frequency, type of motion (elliptical or linear) and the angulation of the tip to the deposit or tooth surface.[25]

The water exiting the tip has been shown to have 3 physiologic effects on the plaque biofilm. Acoustic microstreaming is the flow of water caused by the ultrasonic waves. Acoustic turbulence is created by the rapid movement of the tip resulting in a swirling effect of the water, and cavitation is the formation of bubbles that implode and create additional turbulence.

The piezoelectric ultrasonic dental unit consists of a base (generator), a hand piece that houses a crystal transducer and a foot pedal. The tip is attached to the hand piece with a wrench, and depressing the foot pedal sends an electrical current to the crystal transducer that converts electrical energy to mechanical energy. This results in rapid vibrations that cause the working end of the tip to vibrate in a linear motion. The magnetostrictive ultrasonic instrument consists of a generator, foot pedal, hand piece and a transducer, also known as an insert. The transducer or core is a stack of metal strips or ferromagnetic rod that is attached to the working end or tip. A copper wire coil found in the hand piece produces a magnetic field within the transducer when the foot pedal is depressed and electrical energy is created. The process of magnetizing and demagnetizing causes the core to contract and return to its original shape. This fluctuation in the electromagnetic field causes the tip to vibrate in an elliptical 360° movement (Table I). Unlike the piezoelectric, this elliptical motion allows any portion of the insert to adapt to the tooth surface.[26,27]

Table II: Suggested Use of Piezoelectric and Magnetostrictive Ultrasonic Instruments (from Flemmig et al)[28]

Piezoelectric		
Tip Angulation	Lateral Pressure	Power Setting
0°	0.5 N to 2 N	Low – Medium
45°	0.5 or 1 N	Low
	0.5 N	Medium
90°	0.5 N	Low
Magnetostrictive		
Tip Angulation	Lateral Pressure	Power Setting
0°	2 N	Low
45°	0.5 N	Low – Medium

A main concern during periodontal instrumentation is the unnecessary removal of the root surface while striving to remove deposits. A study by Flemmig et al analyzed defect depth and defect volume using extracted teeth mounted on resin and instrumented on 1 root surface with the piezoelectric technology.[28] To prevent extensive root substance removal exceeding more than 50 µm per year, the authors recommended any combination of:

- 0° tip angulation, 0.5 N to 2 N lateral force and low to medium power
- 45° tip angulation, 0.5 N or 1 N lateral force and low power setting
- 45° tip angulation, 0.5 N lateral force and medium power setting
- 90° tip angulation, 0.5 N lateral force at a low power setting

A similar study conducted by the same authors using the magnetostrictive ultrasonic instrument reported similar results (Table II).[29]

Contemporary Ultrasonic Instrumentation in Therapy: A landmark in vitro study carried out by Busslinger et al compared magnetostrictive, piezoelectric and curets with regard to time taken for instrumentation, calculus removal and root surface roughness.[18] The researchers reported no statistical significant difference in calculus removal when comparing the 3 treatment modalities. The study also showed that of the 3 instruments used, the magnetostrictive device produced the smoothest root surface. Conversely, Cross–Poline et al also compared the effects of the magnetostrictive and piezoelectric ultrasonic instruments.[30] The authors concluded that the piezoelectric instrument produces a smoother root surface than the magnetostrictive. The literature shows that both instruments produce similar therapeutic outcomes. However, there is conflicting evidence in the area of root surface smoothness with studies showing evidence for both technologies.[18,20,30]

Developments in ultrasonic tips, especially the precision thin inserts (PTIs), make ultrasonic instrumentation more effective towards the apex and furcation areas than hand–activated curets because the shape of the tip allows easy access to the root surface.[31] Many of the tips are thin and are designed for site–specific areas depending on where it is to be used and the amount of hard deposits to be instrumented.[31] A systematic review completed by Tunkel et al compared the effectiveness of subgingival hand–activated scaling and ultrasonic instrumentation, and concluded that debridement by ultrasonics was more effective requiring less time than hand–activated instrumentation and also resulted in a less stressful experience for the patient.[8] Additionally, a survey of clinical evaluations with magnetostrictive and piezoelectric technologies utilized by practicing dental hygienists and reported by the Clinical Research Associates concluded that all 16 ultrasonic instruments tested performed adequately in calculus removal.[32] However, the leading performer in calculus removal was the piezoelectric instrument. Both technologies rated equally in tip access, and the magnetostrictive technology rated higher in patient comfort.[32]

Based on a review of the literature, ultrasonic instruments showed no significant difference in therapeutic outcomes when compared to each other and when compared with hand–activated instruments.[5,33–36] When compared to the magnetostrictive unit, the piezoelectric was found to be more efficient in subgingival calculus removal and provided a smoother root surface.[18,30] Currently, in vivo research directly comparing the effectiveness of the magnetostrictive and piezoelectric is non–existent. Multiple authors report that more research is needed in this area for the purpose of comparing treatment variables such as bleeding on probing, clinical attachment levels, calculus removal, time taken for calculus removal and hypersensitivity.[4,18,37,38] The purpose of this study was to compare the clinical endpoint (calculus removal) of the magnetostrictive and the piezoelectric technologies. To simulate dental hygiene practice with patients, the present study was conducted as an in vivo research study.

Methods and Materials

This research study employed a quantitative quasi–experimental randomized split–mouth design using contra–lateral quadrants. A pre– and post–test design for calculus evaluation was used. Participants exhibited light to moderate amounts of non–tenacious subgingival calculus on buccal, mesial, distal and lingual surfaces of selected test teeth and surfaces. Calculus on root surfaces was measured using the Suter 2R/2L design explorer.

Prior to conducting the clinical study, approval was obtained from the Idaho State University Human Subjects Committee. The committee approved the study under the provisions of Federal Regulations 45 CFR 46. All participants in the study signed and provided informed consent. The principal investigator followed a strict protocol regarding the ethical and confidentiality rights of the participants. All data collection forms were confidential, randomly coded and anonymous to everyone except the researcher.

New and existing patients of a dental hygiene clinic were contacted by phone for this clinical study. Eighteen adults met the inclusion criteria that included the need for initial periodontal therapy, an age range between 18 and 65, moderate non–tenacious subgingival calculus on 6 test sites of contra–lateral quadrants, a minimum of 6 teeth in a selected quadrant and no contraindications to ultrasonic instrumentation. Test sites included a molar (ML and B), premolar (DB and L) and incisor (DL and MB) in contra–lateralal quadrants. In the pre–test evaluation, the data collector classified the root surface and presence of calculus using the following scale: 0 (non–existent), 1 (rough), 2 (light) and 3 (moderate). The clinical and teaching experience of the data collector in calculus evaluation contributed in establishing validity and intra–rater reliability. The data was recorded on the dental chart available on the pre–test calculus evaluation form.

The data collector assigned the arch for instrumentation and a coin–flip was used for random treatment assignment of instrument. A stopwatch was used to time 20 minutes for each quadrant of instrumentation. The clinician was blind to the test surfaces and treated the entire quadrant(s) with each instrument. At the completion of instrumentation, the data collector classified the root surface and presence of calculus using the 4 point scale: 0 (non–existent), 1 (rough), 2 (light) and 3 (moderate).

Two newly acquired ultrasonic instruments with new PTIs were set–up side–by–side with easy access from the clinician's sitting position. The straight PTI was inserted or attached to both ultrasonic units for initial instrumentation. The clinician started instrumentation in the anterior, specifically at the central incisor, and moved distally to the canine. The clinician changed tips twice (once for the Right PTI and once for the Left PTI) during the timed instrumentation. In the posterior, the R/L insert was positioned at the distobuccal (DB) or distolingual (DL) line angle and instrumentation was in a buccal/lingual–mesial direction to the midline of the mesial proximal surface. The clinician then adapted R/L tip at the DB/DL line angle and instrumented to the midline of the proximal distal surfaces. The Cavitron Plus® was provided by Dentsply International® and the PTIs used were the universal straight FSI–SLI 10–S for anterior instrumentation, and for posterior scaling the FSI– SLI 10R and the FSI–SLI 10L inserts were used. The Symmetry IQ 3000 series piezoelectric ultrasonic was provided by Hu–Friedy® (Chicago, IL). The 100 Thin Universal S–Series (US 100) (DENTSPLY Professional Division, York, PA) for anterior instrumentation, the Right Perio S–Series (US4R) (Hu–Friedy, Chicago, IL) and the Left Perio S–Series (US4L) were used for posterior instrumentation.

The clinical and teaching experience of the data collector in addition to previous calibration with peers in calculus evaluation contributed in establishing intra–rater reliability. The clinical experience of the clinician contributed in establishing intra–rater reliability of instrumentation. In addition, an experienced dental hygiene educator observed the ultrasonic techniques with both technologies through repeated use of both ultrasonic instruments with the PTIs. The clinician was evaluated on specific criteria developed for subgingival instrumentation with both technologies prior to data collection. Data were analyzed using a pre– and post–test design with an ordinal measurement on a 4 point scale (0, 1, 2, 3). The clinical and teaching experience of the data collector, in addition to previous calibration with peers in calculus evaluation, contributed in establishing intra–rater reliability. One examiner was used. Each of the 6 test surfaces per quadrant was assigned a score and the sum of the 6 surfaces in each quadrant (0 to 18) was used for the analysis of variance (ANOVA) calculation. The ANOVA with repeated measures analyzed the pre– and post–test calculus data ($p \leq 0.05$).

Results

There were 18 participants in the pilot study (Table III). The majority of the participants were male (62%, n=11), between the ages of 18 to 30 years of age (38%, n=7). Most did have a dentist of record (77%, n=14) and all except 1 reported not having dental insurance (94%, n=17). All participants reported not having a medical doctor of record (100%, n=18).

Table III: Demographic Variables of the Participants

Characteristics	Participants	Percent
Gender	Female	38% (n=7)
	Male	62% (n=11)
Age Range Mean Age: 38	18–30 years	38% (n=7)
	31–43 years	22% (n=4)
	44–56 years	33% (n=6)
	56–65 years	6% (n=1)
Dental Insurance Coverage	Yes	6% (n=1)
	No	94% (n=17)
Physician of Record	Yes	0% (n=0)
	No	100% (n=18)
Dentist of Record	Yes	22% (n=4)
	No	77% (n=14)

Table IV: ANOVA Within–Subjects Effect: Results of pre–test/post–test calculus evaluation within subjects including tooth surfaces and by technology

Source	df	F	p
Pre–test/Post–test	1	1121.31	0.000
Error (Pre–test/Post–test)	17		
Technology	1	0.05	0.813
Error (Technology)	17		
Pretest/Posttest Technology	1	0.00	1.000
Error (Pre–test/Post–test Technology)	17		

Table IV illustrates the within–subjects effect of the pre– and post–test calculus evaluation. The main effect for test was significant $F(1,17)=1121.3$, $p<0.05$), but neither the interaction of test by technology $F(1,17)=.01$, $p>0.05$) nor the pre– and post–test by technology $F(1,17)=Ø$, $p>0.05$ were significant.

Table V represents pre– and post–test calculus assessment values for both technologies. The estimated marginal means of the pre– post–test data of calculus assessment for both ultrasonic techniques are reported with a pre–test mean of 17.7 and post–test mean of 4.4. The standard error of the mean is reported as 0.1 for the pre–test and 0.3 for the post–test.

The data in Table VI represents calculus evaluation for each individual technology by combining the results of the pre– and post–test. Eleven is the estimated mean (0.2 standard deviation) of calculus present for both technologies. Again, both technologies had identical amounts of calculus present at the pre– and post–test evaluations.

Table VII represents the change in calculus data from the pre–test to post–test evaluations. Both technologies reported a pre–test mean of 17.7 and a standard error of 0.1 and the post–test mean of 4.4 and standard error of 0.4. Therefore, ANOVA reveals no statistically significant difference in calculus removal between technologies.

The bar graph in Figure 1 shows the similarities in the results of calculus evaluation for both technologies. The grey bars represent the pre–test mean value of 17.7 and the black bars represent endpoint mean of 4.4. Table VIII shows that there is no statistically significant difference in calculus removal between both ultrasonic technologies (df=1, p=0.8).

Discussion

The results of this study are in agreement with the literature that measures therapeutic endpoint of both ultrasonic instruments.[3,5,39] One explanation is that the therapeutic endpoint depends heavily on the outcome of the clinical endpoint.

In this study, the operator was permitted 20 minutes for instrumentation in each quadrant. However, if the clinician felt that the root surfaces were smooth as detected with the PTI, instrumentation of that quadrant could cease. The post–test evaluation determined that calculus remained in both quadrants regardless of the technology used and neither technology effectively removed calculus within this 20 minute period. Therefore, this study suggests that more than 20 minutes of instrumentation per quadrant is required for adequate removal of light–moderate subgingival calculus. In addition, it is recommended that ultrasonic instrumentation be followed by hand–activated instrumentation with curets as well as an explorer to assess root surfaces after instrumentation. The appropriate clinical endpoint cannot be reached with ultrasonic instrumentation alone within this timeframe. This practice should also be applied during periodontal maintenance procedures. The results of this study could also suggest that the PTIs do not provide enough tactile sensitivity to render the root surface smooth.

The results of this study are in agreement with an in vitro study conducted by Busslinger et al who

Table V: Estimated Marginal Means Pre–test and Post–test Data

Calculus Assessed	Mean	Standard Error
Pre–test	17.7	0.1
Post–test	4.4	0.3

Note: Specific sites on a molar (ML, B), premolar (DB, L) and incisor (DL, MB) were used to assess outcome of scaling in both quadrants.

Table VI: Estimated Marginal Means of Calculus Score of Both Technologies

Technology	Mean	Standard Error
Magnetostrictive	11.0	0.2
Piezoelectric	11.0	0.2

Table VII: Estimated Marginal Means of Pre–test and Post–test for Each Technology

Pre–test/ Post–test	Technology	Mean	Standard Error
Pre–test	Magnetostrictive	17.7	0.1
	Piezoelectric	17.7	0.1
Post–test	Magnetostrictive	4.4	0.4
	Piezoelectric	4.4	0.4

Figure 1: Mean Values for Pre–test and Post–test Calculus Evaluation for Both Technologies

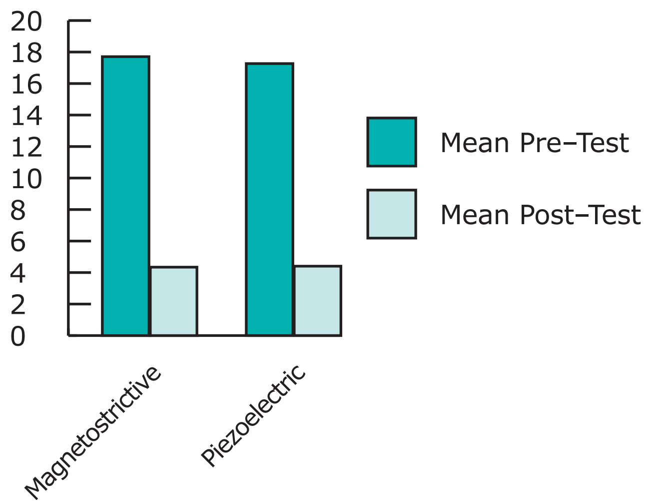


Table VIII: ANOVA Summary Table for Calculus Removal by Ultrasonic Technique

Source	df	F	Type III SS	MS	p
Technologies	1	0.0	0.0	0.0	0.8

reported no difference in calculus removal between the magnetostrictive, piezoelectric and hand instrumentation.[18] In Busslinger's study, instrumentation stopped when the area was "clean and smooth" when examined visually and with an explorer.[18] In the present study, the clinician ceased instrumentation when root surfaces were smooth with the PTI. The authors reported that both ultrasonic instruments removed similar amounts of calculus. The clinician scaled the teeth mounted on stents, which provided much more visual access to root surfaces than any clinician providing instrumentation intra–orally. Even with this accessibility to different areas of the roots, the clinician was still unable to remove all of the calculus on the root surfaces.

Suggestions for future studies include using the same research design to analyze clinical and/or therapeutic outcomes for periodontal maintenance patients. A study conducted by Chapple et al studied the therapeutic outcomes after instrumentation with an ultrasonic unit at full power and at half power, and found that both settings provided similar healing outcomes.[40] Therefore, studies are needed to evaluate ultrasonic scaling with regard to power setting.

Conclusion

With regard to the hypothesis of this study, the results show that there is no statistically significant difference in calculus removal when comparing the magnetostrictive and piezoelectric ultrasonic technologies. This pilot study has provided information about calculus removal that can encourage dental and dental hygiene educators to incorporate both ultrasonic technologies into the clinical curriculum. It also provides insight to the dental and dental hygiene student on the differences and similarities of both technologies. It is important to expose dental and dental hygiene students to different technologies available so that they can make an educated decision about what technology they prefer for periodontal therapy.

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