Comparison of sonic and ultrasonic phacoemulsification using the Staar Sonic Wave system

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Purpose: To compare the performance of sonic phacoemulsification with that of ultrasonic phacoemulsification in regard to 1-day postoperative visual acuity, corneal edema, and procedure efficiency.

Setting: Oregon Eye Institute, Eugene, Oregon, USA.

Methods: This prospective nonrandomized study comprised 86 eyes with mild to moderate nuclear sclerotic cataract. Forty-three eyes had sonic and 43 ultrasonic phacoemulsification using the Staar Sonic Wave phacoemulsification system. The mean age was 76 years in the ultrasonic group and 71 years in the sonic group. The mean nuclear sclerosis was 2.0+ in the sonic group and 1.9+ in the ultrasonic group. Patient age, lens density, postoperative corneal edema, 1-day postoperative uncorrected visual acuity (UCVA), and the percentage of eyes with a visual acuity of 20/40 or better were determined. In addition, the mean ultrasonic and sonic times, mean percentage phaco power, and mean effective phaco time (EPT) were calculated in each group.

Results: Both groups had a 5% incidence of trace corneal edema. The mean UCVA was 20/41 in the ultrasonic group and 20/42 in the sonic group. Seventy-nine percent of eyes in the ultrasonic group and 74% in the sonic group had a UCVA of 20/40. The mean percentage phaco power was 7.2% and 7.6% in the ultrasonic group and sonic group, respectively. The mean EPT was low in both groups, 4.0 and 2.9 seconds, respectively.

Conclusion: Sonic technology yielded outcomes similar to those of ultrasonic phacoemulsification with respect to postoperative visual acuity and corneal edema in patients with average density nuclear sclerotic cataract.

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The past decade has given rise to some of the most profound advances in phacoemulsification technique and technology. Techniques for cataract removal have moved from those that use mainly ultrasound energy to emulsify nuclear material for aspiration to those that use greater levels of vacuum and small quantities of ultrasonic energy for lens disassembly and removal. Advances in phacoemulsification technology have made these changes possible by providing greater amounts of vacuum in addition to ultrasonic power modulations that allow more efficient use of ultrasound energy with greater safety in the delicate intraocular environment.[1,2]

Although phacoemulsification permits safe removal of cataractous lenses through astigmatically neutral small incisions, current ultrasonic technology has drawbacks. Ultrasonic tips create both thermal and cavitational energy. Thermal energy is produced from internal intermolecular friction[3] and external friction with surrounding objects. Internal heating of the tip and friction of the tip against incisional tissues can create corneal incision burns.[4]

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Incisional burns in clear corneal incisions may result in a loss of self-sealability, corneal edema, and severe induced astigmatism.[5] Cavitational energy results from fluid pressure waves emanating from the tip in all directions.[6] Increased cavitational energy may accompany phacoemulsification of dense nuclei and may also damage the corneal endothelium, producing corneal edema.

A relatively new machine for cataract extraction is the Staar Sonic Wave. The Sonic Wave was designed to combine traditional ultrasonic phacoemulsification technology with new features including innovations in energy delivery, high-vacuum tubing, and digitally recorded video overlays. The revolutionary feature of this machine is its incorporation of sonic energy as an alternative to ultrasound phacoemulsification. Sonic technology removes cataractous material without generating heat, as occurs with the use of ultrasonic technology.

A conventional phaco tip moves at ultrasonic frequencies between 25 kHz and 62 kHz. The 40 kHz tip expands and contracts along its axial length 40 000 times per second, generating heat caused by intermolecular frictional forces within the shaft of the tip and external friction that can be conducted to the surrounding tissues. The amount of heat should be directly proportional to the operating frequency. In addition, cavitational effects from the high-frequency ultrasonic waves generate even more heat.[6,7]

Sonic technology operates at a frequency much lower than ultrasonic frequencies. Its operating frequency is in the sonic rather than the ultrasonic range, between 40 Hz and 400 Hz. This frequency is 0.1% to 1.0% that of ultrasound, resulting in frictional forces and related temperatures that are theoretically proportionally reduced. In contrast to ultrasonic tip motion, the sonic tip moves back and forth without changing its dimensional length. The tip of an ultrasonic handpiece can reach extreme temperatures in a few seconds, while the tip of the Wave handpiece in sonic mode barely generates any heat. This reduction in heat occurs by elimination of intermolecular friction within the tip and diminution of external friction from a reduction in tip speed. We have demonstrated this by grasping a phacoemulsification needle with bare fingers in sonic mode without perceived increases in tip temperature. In addition, the sonic tip does not generate cavitational effects so true fragmentation, rather than emulsification of the lens material, takes place (personal communication, Alex Urich, Staar Surgical, April 2, 2001).

One might surmise that this reduction in heat and cavitational energy in sonic mode would lower the likelihood of incisional burns and corneal endothelial trauma and perhaps lead to clearer corneas and better visual acuity in the immediate postoperative period. To document the potential advantages of sonic technology over ultrasonic technology, we performed a study of eyes having cataract extraction with sonic technology and with ultrasonic technology. The parameters of 1-day postoperative visual acuity and corneal clarity were analyzed.

Patients and Methods

This prospective nonrandomized study comprised 86 eyes with mild to moderate nuclear sclerotic cataract and no other ocular pathology. Although there was a statistically significant difference in age between groups ($P < .004$), the degree of nuclear sclerosis was similar ($P > .16$) (Table 1).

Forty-three patients were assigned to have ultrasonic phacoemulsification and 43 sonic fragmentation using the 2 separate modes of the same Staar Wave phacoemulsification machine. All surgeries were performed by 1 surgeon (I.H.F.) using the choo-choo chop and flip phacoemulsification technique.[1]

The patients' age, lens density (from 0 to 4+), 1-day postoperative uncorrected visual acuity (UCVA), and degree of central corneal edema (0 to 4+ microcystic edema or 0 to 4+ Descemet's folds) were documented by the operating surgeon. In addition, the following machine parameters were recorded directly from the machine's data screen: mean percentage phaco power and ultrasonic/sonic time. The mean percentage phaco power measurements were given for both ultrasonic and sonic modes and essentially described the average percentage of the total available power used for lens removal with either mode. These measurements were used to calculate the effective phaco time (EPT).

The EPT is essentially the time it would take to remove the cataract if continuous 100% "phaco power" were used in ultrasonic or sonic mode. The EPT was calculated by multi-

Table 1. Clinical characteristics: mean results.

Characteristic	Ultrasonic	Sonic
Age (y)	76	71
Nuclear sclerosis grade	2.0+	1.9+
Corneal edema (%)	5	5
Visual acuity	20/41	20/42
Visual acuity ≥20/40 (%)	79	74

plying the mean percentage phaco power by the time and dividing by 2. The product is divided by 2 because pulse mode is used in the choo-choo chop and flip technique and thus power is only being delivered 50% of the time.

Statistical analysis was performed by inserting data into an Excel spreadsheet and using the unpaired *t* test to compare each set of data for each group.

Results

Two patients in each group developed trace corneal edema presenting as trace Descemet's folds 1 day postoperatively (Table 1). The mean UCVA 1 day postoperatively was 20/41 in the ultrasonic group and 20/42 in the sonic group ($P > .45$) (Table 1).

Table 2 shows the machine parameter results. The mean percentage phaco power in both groups was similar ($P > .33$). Patients in the sonic group required greater ultrasonic/sonic time than patients in the ultrasonic group; the difference between groups was statistically significant ($P < .008$). Although there was a statistically significant difference between the 2 groups in EPT ($P < .03$), both had extremely low EPTs.

Discussion

As newer machines for cataract surgery become available, claims of superiority of 1 machine or 1 technology over another have naturally ensued. These claims have mainly used the mathematically derived EPT required to remove the cataractous lens to measure the efficacy of a machine. Unfortunately, because of a lack of standardization in the ultrasound frequencies between machines, comparison of the EPT between machines does not give an accurate assessment of the actual energy delivered into the eye, preventing efficacy comparisons. Thus, we compared 1 technology (ultrasonic energy) to another (sonic energy) using the same phaco machine for cataract extraction.

Table 2. Machine parameters: mean results.

Parameter	Ultrasonic	Sonic
US or sonic time (s)	76	101
Percentage phaco power (%)	7.2	7.6
Effective phaco time (s)	2.9	4.0

US = ultrasonic

By using 1 experienced surgeon and assessment of preoperative lens density and postoperative corneal edema, variables were minimized in the study. The 2 groups of patients were equally matched in mean lens density. Although we believed that there would be a difference between eyes having sonic fragmentation and those having ultrasonic phacoemulsification, there were no significant differences in the incidence of corneal edema, the mean 1-day postoperative visual acuity, or the percentage of eyes having a final visual acuity of 20/40 or better. With regard to machine parameters, the sonic mode was less efficient than the ultrasonic mode, requiring 33% greater sonic time. However, both groups had extremely low EPTs.

Ultimately, we concluded that in patients with nuclear sclerotic cataracts of average density having phacoemulsification using power modulations, sonic technology gave outcomes similar to those of ultrasonic technology with respect to the immediate postoperative UCVA and corneal edema. We were unable to demonstrate improved outcomes with the sonic mode. Although the sonic group had an EPT similar to that of the ultrasonic group, the sonic tip operates at a much lower frequency than the ultrasonic tip. Thus, a proportionally lower amount of energy should be introduced into the eye.

The most important question perhaps is whether this lower energy is clinically significant. Apparently in normal eyes with cataracts of average density having efficient surgery by an experienced surgeon, it is not. However, we believe there may be a difference in compromised eyes with corneal endothelial dystrophy or decreased endothelial cell counts from previous intraocular surgery or inflammatory insults. One must also ask whether the difference in delivered energy would become more clinically apparent in eyes with greater nuclear sclerosis, in which greater amounts of energy would need to be introduced into the eye.

One final theoretical consideration involves surgeon experience and technique. In this study, the surgery was performed using an extremely efficient chopping technique that has been shown to introduce minimal amounts of energy into the eye.[2,8] Perhaps the true value of sonic technology will become apparent in the hands of inexperienced surgeons or residents using less efficient divide-and-conquer phacoemulsification techniques,[8] where the differences in energy between sonic and ultrasonic modes would be more clinically significant.

Ultimately, the clinical value of sonic technology and other alternative energy sources may be best demonstrated by studying high-risk eyes with denser cataracts, comparing sonic to ultrasonic energy and including a measurement of endothelial cell loss as the ultimate determinant of the value of 1 technology over the other.

References

1. Fine IH. The choo-choo chop and flip phacoemulsification technique. Operative Tech Cataract Refract Surg 1998; 1:61–65
2. Fine IH, Packer M, Hoffman RS. Use of power modulations in phacoemulsification; choo-choo chop and flip phacoemulsification. J Cataract Refract Surg 2001; 27: 188–197
3. Mason WP. Physical Acoustics and Properties of Solids. Princeton, NJ, D Van Nostrand Co, 1958
4. Majid MA, Sharma MK, Harding SP. Corneoscleral burn during phacoemulsification surgery. J Cataract Refract Surg 1998; 24:1413–1415
5. Sugar A, Schertzer RM. Clinical course of phacoemulsification wound burns. J Cataract Refract Surg 1999; 25: 688–692
6. Gooberman GL. Ultrasonics; Theory and Application. New York, NY, Hart Publishing Co, 1963
7. Seibel BS. Phacodynamics: Mastering the Tools and Techniques of Phacoemulsification Surgery, 3rd ed. Thorofare, NJ, Slack, 1999
8. DeBry P, Olson RJ, Crandall AS. Comparison of energy required for phaco-chop and divide and conquer phacoemulsification. J Cataract Refract Surg 1998; 24:689–692

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