Meniscal Debridement With an Arthroscopic Radiofrequency Wand Versus an Arthroscopic Shaver: Comparative Effects on Menisci and Underlying Articular Cartilage

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Purpose: Meniscal debridement with an arthroscopic radiofrequency (RF) wand versus an arthroscopic shaver and their comparative effects on menisci and underlying articular cartilage were studied. **Methods:** When repair is not feasible, degenerative or post-traumatic meniscal tears often need debridement. Six fresh bovine knees were harvested, the tibial plateau was dissected free from the femoral articulation and placed in a saline bath at 28°C, with 10% to 15% of the posterior horn of menisci debrided arthroscopically, and the surfaces debrided using a basket punch plus shaver, punch plus RF wand, RF wand alone, and untreated control. Treatment time of each case was 24 seconds at wand power 7. We characterized an injury zone, as well as viability and metabolic activity of meniscal cells and tibial articular cartilage chondrocytes. **Results:** Chondrocyte viability of the tibial articular surface was 96% to 98%. We saw no differences in viability or injury zone (0 to 150 μm) among debrided groups or versus the control for any experimental surface, with no significant difference in metabolic activity in menisci debrided surfaces versus control. Meniscal viability was variable with analyses showing substantial levels (150 to 500 μm) of cell death in debrided and control groups. Metabolic activity in treated meniscus was lower than in cartilage specimens. No significant differences were observed among treatment groups versus control. **Conclusions:** Focal areas of chondrocyte cell death were not seen. Meniscal samples showed cell death (150 to 500 μm) throughout the tissue. **Clinical Relevance:** Debridement of menisci with a bipolar RF wand produces levels of cell injury and death similar to those of debridement with a basket punch mechanical shaver. The RF wand did not harm underlying articular surfaces and produced a precise cut to the meniscal surface. **Key Words:** Meniscal debridement—Radiofrequency wand—Arthroscopic shaver—Meniscal tear.

Although the meniscus is critically important for knee motion, load distribution, and articular congruency, degenerative or post-traumatic tears often necessitate debridement or repair. When repair is not feasible, careful debridement, often with an arthroscopic punch and/or shaver, becomes a treatment mainstay. In the majority of cases, significant pain relief can be accomplished. A subset of patients, however, do not respond as well, their pain being either minimally changed or relieved for only a short period of time. Many reasons may account for these less favorable outcomes, but one possibility is that the meniscal debridement itself could have been suboptimal. Limitations to an optimal meniscal debridement can include the arthroscopic instrumentation, the body's repair response or lack of response to partial meniscectomy, the precise amount and location of meniscus debrided to adequately relieve symptoms, patient compliance, and the operative technique. Ample resection without appropriate healing could lead to

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subsequent meniscus failure, reinjury, and/or articular cartilage damage and early degeneration. To circumvent some of these possibilities, advances in instrumentation and debridement modalities have been explored.

One such advance is the introduction of electrosurgical arthroscopy, which has spawned studies on its use for meniscal and cartilage debridement.[1-3] Published reports of electrosurgical devices in arthroscopy began in 1979 for their use in knee synovectomy,[1] with most of the studies using monopolar radiofrequency (RF) energy instruments. Bovie-type monopolar devices dissipate energy from the electrode through the patient to ground at a distant site. This leads to "scattering," decreased current density at the point of application, and damage to the surrounding tissues.[1-3] Bipolar devices place both electrodes very close to one another, passing the current only through the tissue in which they are being applied. This leads to increased current density at the treatment site, increasing efficiency, and decreasing damage to adjacent tissue as the wand "vaporizes" the tissue to which it is applied.

Methods of the early electrosurgical studies in arthroscopy dealt mostly with monopolar devices.[3] In essentially all of these studies, laser and electrosurgical devices injured both cartilage and meniscal tissues to variable depths, ranging from nearly undetectable to as much as 1,980 μm in depth.[3,4] Studies suggested that monopolar RF energy may produce greater thermal injury on menisci and cartilage than bipolar devices, but in 2002, Vangsness et al.[5] characterized bipolar-induced thermal injury on human meniscal tissues. In their study, thermal injury depth on human menisci averaged 550 μm. However, as in many other studies, despite good controls, they observed large variations within experimental groups.

There are currently no controlled studies comparing patient outcomes with meniscal debridement using an RF wand versus a mechanical shaver. However, Owens et al.[6] have recently reported a prospective, comparative study for the treatment of grade 2 and 3 patellar chondral lesions, showing that RF treatment produced clinical outcomes superior to debridement with a mechanical shaver. Analysis of the effects of RF wand debridement techniques on tissue at the microscopic level, and correlating this to successful clinical outcomes, may be an even more difficult task. One recent study on cartilage reported that well-controlled RF bipolar wand debridement of cartilage produces a defined margin of chondrocyte death extending approximately 100 to 200 μm deep to the treatment area.[2] They also found no significant changes in chondrocyte metabolic activity at the injury site. These findings begin to characterize the injury zone in cartilage beyond the debridement site, but similar studies in the meniscus are lacking.

Therefore, the present study was performed (1) because of the large variability of "thermal injury" reported in the literature during RF wand use and (2) because studies detailing viability and metabolic activity of meniscal cells and chondrocytes at underlying meniscal debridement sites are lacking. In this study, we characterized such parameters, attempting to define a zone of injury following meniscal debridement with a bipolar RF wand in a controlled setting. We hypothesized that no difference exists in cellular viability, metabolic activity, and zone of injury during meniscal debridement with an arthroscopic RF wand versus an arthroscopic shaver.

METHODS

Experimental Model

A validation study has been previously performed for the use of bovine articular cartilage in viability and metabolic activity studies.[2] We have also used 1 surgeon to perform the debridement on the fresh bovine menisci, as close to the operative setting as possible. We observed that chondrocyte viability was preserved in knee joints for a period of 3 to 6 days. In the present study, fresh calf knees were used within 24 hours of death. En bloc knees were stored at 4°C before experimentation. The knee joints were opened under sterile conditions using a medial parapatellar arthrotomy and the tibial plateaus were carefully dissected free from the femoral articulation. Meniscal ligaments, as well as menisci, were kept intact with the tibial plateau. The proximal tibia was cut to allow for adequate submersion of the plateau in an arthroscopic bath. Experiments were performed on 2 bovine knees per experiment (on 3 separate days) using an identical protocol, timing, and sequence of events. In total, 6 fresh bovine knees were carefully dissected, placed in a saline bath at 28°C, and under arthroscopic conditions, approximately 10% to 15% of the posterior horn of each meniscus (except control) was debrided. Per experiment, the 4 surfaces of the 2 knees were carefully labeled as follows (Figs 1 and 2):

1. Knees 1, 3, and 5: Lateral tibial plateau (LTP1)—basket punch plus shaver. Medial tibial plateau (MTP2)—punch plus RF wand.

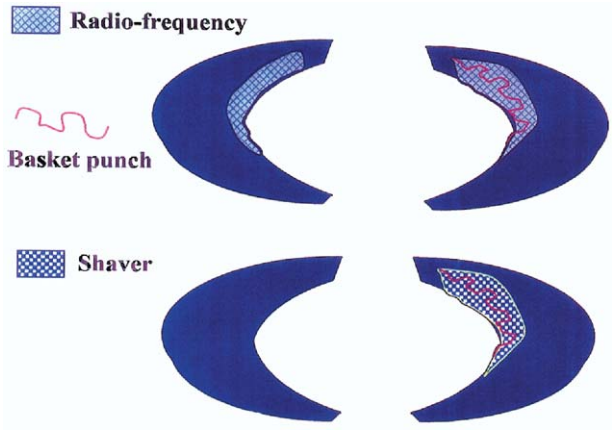

FIGURE 1. Schematic diagram of meniscal treatment areas for each experiment.

2. Knees 2, 4, and 6: Medial tibial plateau (MTP3)—RF wand alone. Lateral tibial plateau (LTP4)—no treatment, control group.

RF Probe and Meniscal Debridement

The 2.5-mm 90° wand is a bipolar multi-electrode arthroscopic probe consisting of 7 active electrodes inserted inside an alumina ceramic spacer, placed inside a stainless steel return electrode 2.2 mm in diameter. The tip of the device is oriented at 90° to the 2.4-mm stainless steel shaft. Each active electrode consists of a titanium wire 0.38 mm in diameter and 0.4 mm in length. The ceramic spacer separates the active electrodes from the return by a 2-mm gap.

The total time of meniscal treatment, for all modalities, was 24 seconds. The Razorvac (ArthroCare, Sunnyvale, CA) wand power was set at 7 for all studies. Meniscal debridement was carried out in a freehand manner, in the same fashion for each treatment group, by the senior orthopaedist author. In cases where 2 modalities were used, the total time of treatment was still 24 seconds.

In all cases, a blunt-ended right-angle hook was used to gently elevate the meniscus before any treatment in an attempt to simulate the floating effect of the posterior horn achieved with fluid during conventional arthroscopy. Basket punch use generally corresponded to punching out about 10% of the posterior horn of the meniscus, allowing us to leave the punched-out and somewhat frayed edges ready for debridement by either the RF wand or the arthroscopic shaver. The

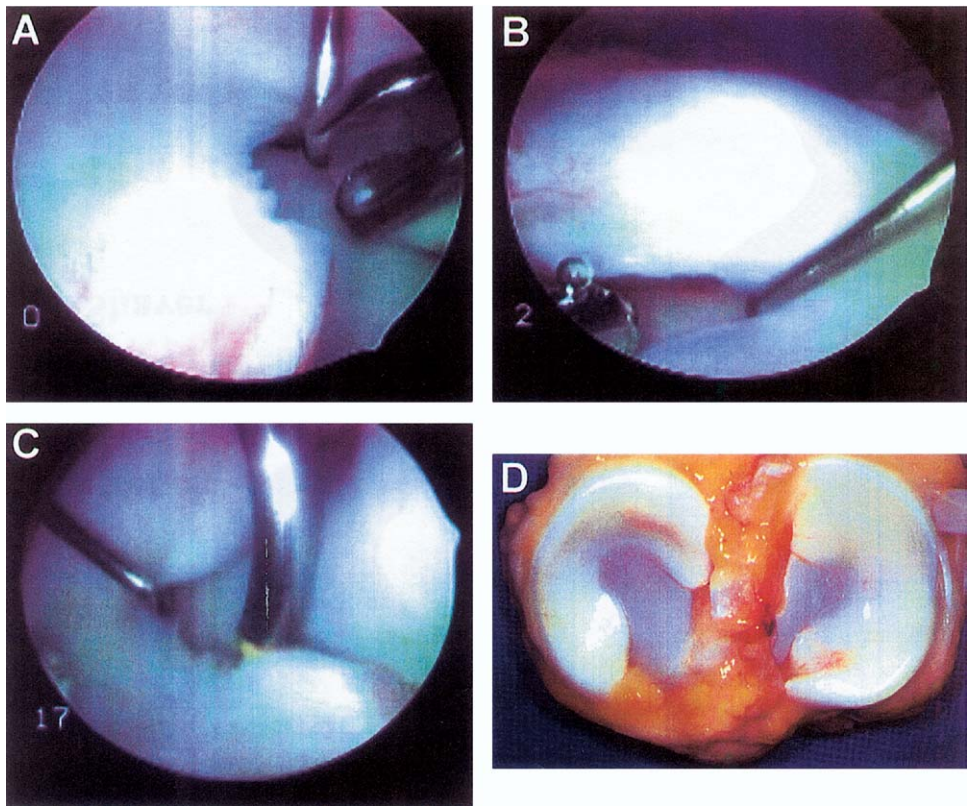

FIGURE 2. Gross appearance of calf menisci after treatment by (A) arthroscopic basket punch, (B) arthroscopic basket punch followed by mechanical shaver, and (C) arthroscopic basket punch followed by RF wand. (D) An untreated control meniscus.

arthroscopic shaver was used in standard fashion, orienting the guarded portion of the shaver toward the articular cartilage surface during meniscal debridement. During wand debridement, the probe was oriented at approximately 60° to the meniscal surface and the elevated meniscus debrided in a light contact mode, passing at a linear rate of approximately 3 to 5 mm/second across the surface. The tibial articular surface and the menisci were kept submerged in the saline bath during treatment. A fluid-flow system was created during treatments to simulate a normal arthroscopic environment. Despite dedicated attempts to keep each treatment identical from sample to sample, the ultimate control over experimental variability, amount of instrument pressure, and angle of operation of specific debrided areas lies in the hands of the surgeon, just as it does clinically. For this reason the senior orthopaedic surgeon was the only person performing the procedure.

Immediately after meniscal debridement, the treatment area was marked and plateaus were placed in normal saline solution until sample sectioning (approximately 15 minutes). A No. 20 scalpel blade was used to carefully dissect meniscal treatment zones and the underlying articular cartilage. Isolated meniscal samples included the entire treatment area plus a surrounding 6- to 8-mm margin to ensure adequate samples for analysis of any potential damage. Cartilage samples directly underlying the debridement site were harvested and comprised at least a 10-mm diameter block. As we and others have previously described,[7] full-thickness cartilage (i.e., from superficial cartilage zone to the deep zone–subchondral bone interface of cartilage) was freed from the subchondral bone by sharp dissection, allowing for more precise sectioning of 0.5- to 1.0-mm thick meniscus/cartilage. In fact, because of the relative softness of calf subchondral bone, the ~1.0-mm thick sections often contained subchondral bone. At least 6 of these sliced specimens per group were analyzed for viability/injury zone or metabolic activity. Importantly, in numerous previous studies, we have observed no differences in viability/activity of chondrocytes when cartilage was left on the subchondral bone versus being freed from the subchondral bone.[2,8,9] In radiolabeled $^{35}SO_4$ studies for metabolic activity, it is possible that inclusion of too much "healthy" cartilage or meniscus beyond the zone of debridement could potentially mask any deleterious effects of treatment. We therefore, as previously described,[2] included a margin of only ~3 mm beyond or surrounding the debridement site for metabolic activity/cell viability studies. This was done to standardize sample sizes among groups and to identify possible injury zones more accurately. The 3-mm zone was chosen based on previous reports suggesting that up to 2 mm of cartilage surrounding a treatment zone may sustain injury resulting in chondrocyte death.[10,11]

Chondrocyte Viability

Debridement zone coronal slices of full-thickness (all 3 zones in depth) articular cartilage and meniscus, 0.5- to 1.0-mm thick, were double stained before confocal laser microscopy, as previously described.[2,7-9] Samples were placed into a solution containing 2,7′-Bis(2-carboxyethyl)-5 (6)-carboxyfluorescein, acetoxymethylester (BCECF-AM), and propidium iodide (PI). BCECF-AM is a fluorescein derivative metabolized by nonspecific esterases in living cell membranes to a green fluorescent product. PI is normally excluded from living cells by the intact cell membrane, but penetrates nonviable cells and intercalates with the DNA and fluoresces red.[12,13] Specimens in solution were placed in a 37°C CO_2/O_2 incubator for 35 to 40 minutes and then removed for microscopic examination. Each articular cartilage layer (superficial, middle, and deep) was analyzed simultaneously. Specimens were viewed with a Zeiss LSM 510 Laser Confocal Scanning Microscope equipped with krypton and argon lasers (Carl Zeiss, Thornwood, NY). Images were obtained at multiple random locations within the meniscus or cartilage slice using Zeiss Laser Scanning Systems LSM 510 software. At least 5 images were obtained from each region within each specimen and the average of these taken for statistical analysis. Viable green cells and nonviable red cells were counted and viability tabulated by computer software (Image-Pro Plus 4.1; Media Cybernetics, Silver Springs, MD). A magnification of ×5 allowed complete visualization of both treatment and adjacent normal zones. LSM 510 software allowed us to superimpose calibrated micrometer measurements into the images studied, thus allowing for calculation of the depth of cell death from the surface.[2]

Metabolic Activity via Glycosaminoglycan Synthesis ($^{35}SO_4$ uptake)

Glycosaminoglycan synthesis, as quantified by the amount of radiolabeled sulfate ($^{35}SO_4$) incorporation into the sample tissue/cells, is well described as a marker of cellular metabolic activity.[2,14-17] Specimens designated for metabolic activity were carefully trimmed to include the 2- to 3-mm margins surrounding the debridement zone and then incubated in tissue

TABLE 1. *Meniscus Sulfate Uptake (Metabolic Activity)*

Meniscal Specimens	Metabolic Activity ($^{35}SO_4$)
Specimens 1, 3, 5 lateral meniscus (basket/shaver)	1,771 ± 239 CPM/mg
Specimens 1, 3, 5 medial meniscus (basket/wand)	1,353 ± 649 CPM/mg
Specimens 2, 4, 6 medial meniscus (wand only)	1,723 ± 631 CPM/mg
Specimens 2, 4, 6 control lateral meniscus (no treatment)	1,540 ± 591 CPM/mg

NOTE. Values given as mean ± SD.

culture media containing 5 μCi/mL of $^{35}SO_4$ for 48 hours at 37°C. After incubation, tissue samples were removed, washed with distilled water to remove unincorporated $^{35}SO_4$, then freeze-dried and weighed. The tissue was then hydrolyzed in 1-N NaOH for 2 hours at 65°C and the hydrolysate analyzed in a liquid scintillation spectrometer for quantitation of $^{35}SO_4$ incorporation.[2,14-17] Results were calculated and are reported as counts per minute (cpm) per milligram of dry weight. Slices were taken at random per sample. The mean values are reported in the results of Table 1.

Statistical Analysis

Data are presented as mean ± standard deviation. Values were subjected to analysis by either Student *t* test or analysis of variance for multiple comparisons. Statistical significance was set at $P < .05$.

RESULTS

Chondrocyte Viability and Metabolic Activity

After each meniscal debridement, the articular surface was carefully inspected. It revealed no evidence of scoring or abnormality. Chondrocyte viability was 96% to 98% in all specimens. Cell death occurred primarily in the superficial cartilage zone, as shown in Fig 3. We did not find any focal area of cell death in cartilage beyond the stated 150 μm, regardless of treatment group. There was no difference between

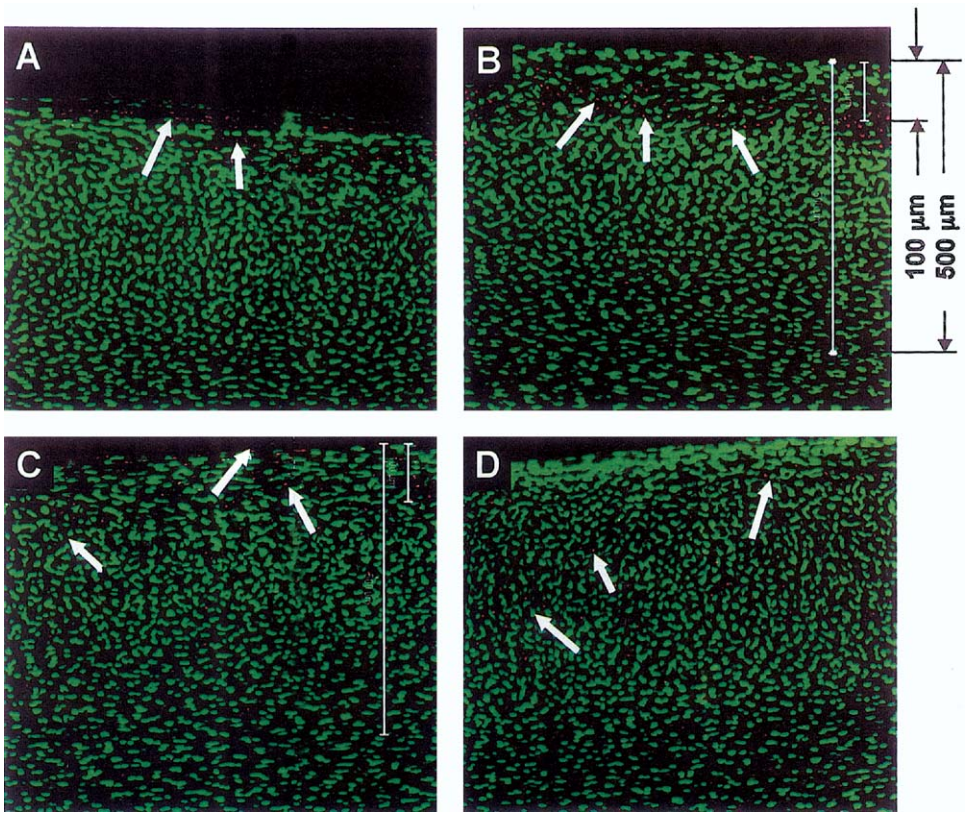

FIGURE 3. Confocal microscopy of calf articular cartilage underlying each experimental debridement site. Chondrocyte death (indicated by red fluorescing cells, arrows) occurred primarily in the superficial layer (100 μm from the surface indicated by the scale in B). Living cells (fluorescing green) represented 96% to 98% of the cell population in all experimental groups. Experimental groups included (A) arthroscopic basket punch plus shaver, (B) arthroscopic basket punch plus wand, (C) RF wand only, and (D) untreated control cartilage. (All images, original objective magnification ×5.)

Table 2. *Articular Cartilage Sulfate Uptake (metabolic activity)*

Tibial Cartilage Specimens	Metabolic Activity ($^{35}SO_4$)
Specimens 1, 3, 5, LTP1	13,070 ± 8,190 CPM/mg
Specimens 1, 3, 5, MTP2	10,110 ± 4,592 CPM/mg
Specimens 2, 4, 6, MTP3	12,690 ± 9,932 CPM/mg
Specimens 2, 4, 6, LTP4, Control	10,520 ± 304 CPM/mg

NOTE. Values given as mean ± SD.
Abbreviations: LTP, lateral tibial plateau; MTP, medial tibial plateau.

debrided groups and control for any of the experiments, and overall chondrocyte viability ranged from 96% to 98% in each experiment. Importantly, focal areas of chondrocyte death, as might be expected from prolonged RF wand energy in one area and should be readily visible in specimens with such robust viability, were not observed in any specimen. This suggests that meniscal debridement with bipolar RF energy, in this setting, did not significantly extend to underlying cartilage.

In general, cartilage had strong sulfate uptake, showing no statistical significance between groups by analysis of variance comparisons (Table 2). Metabolic activity correlates with chondrocyte cell viability. It should be noted that proteoglycan is a fast turnover matrix component in cartilage when compared with collagen and, as expected and observed in this study, it should be much higher in cartilage than in the meniscus (less cellularity and protein synthesis activity in the meniscus).

Meniscus Viability and Metabolic Activity

Gross inspection of the meniscus showed the types of surfaces remaining after debridement with each device. The RF wand left a distinctly smooth, nondiscolored, and more precise surface, unlike the more textured and irregular surface remaining after shaver debridement. In each specimen analyzed within each treatment group, meniscal viability was variable, similar to previous reports of RF thermal injury depths.[5] Most analyses showed substantial cell death throughout meniscal tissue in both debrided *and* control groups. A key finding in this study was that specimens from groups undergoing *any type* of debridement displayed increased numbers of dead cells, most pronounced at debridement sites (Fig 4). Indeed, in each group, treatment with the wand or shaver led to increased levels of cell death beyond the debridement site. Whereas random cell death was noted in each experimental group, the focal death pattern at and beyond debridement sites was not observed in the control specimens. Measurements beyond the site of debridement were typically in the range of 150 to 500 μm (Fig 4). Metabolic activity was lower in the meniscus than in the cartilage specimens, but no significant differences were observed among treatment groups versus control. The data are given in Table 1.

DISCUSSION

The purpose of this study was to compare the effects of bipolar RF energy with those of an arthroscopic shaver and basket punch on meniscal and cartilage cell viability and metabolic activity. These parameters, previously unknown during bipolar RF wand meniscal debridement, were used to characterize a physiologic zone of injury at the site of bipolar wand application. Analysis was both macroscopic and microscopic. Our findings support the hypothesis that no difference exists in these parameters, whether using the RF wand, basket punch, or shaver. Although these data were similar to others in that meniscal "injury" (and its associated measurements) was variable, we did observe a more pronounced injury zone at debridement sites, regardless of which instrument was used. This injury zone was not found in untreated meniscal samples, despite observing variable levels of random cell death. Thus, in using nonhistologic methods to assess cellular damage, we have for the first time shown that, regardless of debridement device, cellular injury occurs at and beyond debridement sites, and to a similar extent, in fresh calf meniscal tissue.

In most reports, meniscal "injury" from RF energy is based on measuring the depth of a fairly well defined "thermal injury" pattern of tissue architecture disruption, identified mainly by histologic examination. Why depth of tissue penetration is so important is due in large part to the idea that a certain depth of RF-induced thermal injury produces nonreparable damage or, produces a potentially more harmful or unstable injury to the surrounding tissue. Subsequently, earlier degeneration and failure result. Although tissue changes caused by RF thermal injury are readily observable, histologic analyses may not be predictive of surrounding cellular activity and injury.[2-4] Moreover, there are a number of differences in tissue staining and analysis techniques reported in RF-injured meniscal tissue. These were some of the more important reasons for using the metabolic activity and cell death assessment techniques herein. Another reason was to assess if the variability in mea-

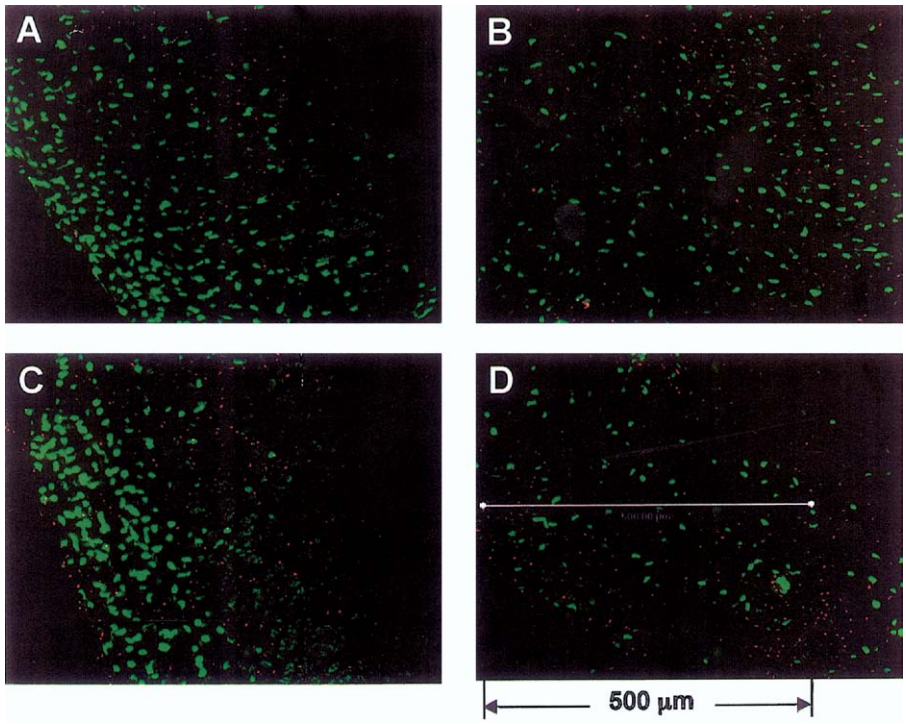

FIGURE 4. Confocal microscopy of calf menisci following experimental debridement treatment. Experimental groups included (A) arthroscopic basket punch plus shaver, (B) arthroscopic basket punch plus wand, (C) RF wand only, and D) untreated control meniscus. Living cells fluoresce green, while dead cells fluoresce red. (All images, original objective magnification ×5. Distance indicated by the 500-µm scale.)

surements of thermal injury extended to the cellular level, which they appear to do in this study as well. Variability in thermal injury depth, after H&E staining/uptake of formalin-fixed specimens, is a rather consistent finding across the literature in relation to studies using RF energy. In menisci, variability is likely due to differences in staining techniques and injury assessment, quantitative differences, RF wand type, wand power, the surface area of the treatment electrode, contact time of electrode with tissue, and the type of current used.[3,4] A recent report suggests that probe geometry and surface area are 2 of the most critical features in determining how deep RF energy penetrates meniscal tissue.[18] There is, however, some evidence that, despite these levels of thermal injury to the meniscus, it often heals to normal tissue in 6 to 7 months.[3,19] These studies reason that less damage to the meniscus (in an "optimal" RF debridement) could translate into less postoperative recovery time.

Whereas the present study used biochemical means to compare a bipolar wand with a basket punch and shaver, studies evaluating the depth of tissue injury of monopolar and bipolar RF energy give insight into how a shaver may compare with both in regard to cellular injury patterns. In cartilage, evidence suggests that during chondral debridement, bipolar RF energy penetrated cartilage substantially more (>2 times the depth) than that of monopolar energy.[11] Further, bipolar RF may lead to cartilage thinning, possibly as a result of tissue penetration, predisposing to further mechanical stress, cartilage loss, and degeneration.[20] In regard to the meniscus, RF debridement of ovine menisci showed that monopolar RF energy left a clear demarcation of thermal injury, fibrochondrocyte nuclear pyknosis, and fusion of collagen fibrils.[21] These authors[21] suggest that thermal injury-induced collagen fibril fusion may actually prevent meniscal tear propagation and stabilize a laceration. Chondral RF debridement has been suggested to provide some resistance to abrasion.[22] RF debridement could lead to the same changes of a smoother surface, less resistance to abrasion, and possibly a more stable rim of tissue.

In the present study, regardless of whether the meniscal surface was roughened with a basket punch or untouched before debridement, RF treatment left the meniscus and its edges clean, precise, and smooth, unlike the mechanical shaver. In theory, a smoother meniscal surface could produce less pain and an improvement in function. While this was in fact suggested in 2 recent studies on cartilage laser ablation,[23,24] it is clear that a strong dependence on the operative surgeon may exist therein, as well as the potential for iatrogenic wand injury. Furthermore, laser treatments can lead to significant damage to the articular cartilage surface, extending

even into the subchondral bone.[25] It is understood that one important reason for meniscal debridement is to produce a stable rim of tissue while minimizing peripheral damage and maintaining circumferential meniscal integrity. Mechanical shavers are not optimally suited for this, often leaving somewhat roughened, less contoured edges in the less accessible areas of the meniscus during arthroscopy. Moreover, the shaver mechanism may cause trauma to the adjacent meniscal tissues during debridement, possibly predisposing to further or more rapid degenerative changes.[26] In fact, cartilage studies show that debridement with mechanical shavers may remove more tissue than with RF energy ablation.[27] If so, determining the true depth of meniscal cell death and remaining cellular activity may be extremely relevant in trying to predict future tissue stability, damage, or a possible reparative response. In a recent report out of the Hospital for Joint Diseases, debrided human meniscal tissue removed with either an ArthroCare wand at power 3 and 7 or with a mechanical shaver, was assessed histologically.[28] Despite significant increases in thermal tissue penetration from 0.18 to 0.33 mm using a wand power of 3 versus 7, they did not observe any "zone of thermal penetration" with a shaver or scalpel. In the present study, however, both the viability and metabolic activity of cells at and surrounding the debridement site were not significantly different than the control.

Finally, the extent and the zone of meniscus requiring debridement are also important considerations. It is known that the central 66% to 75% of the body of menisci is avascular and limited in its capacity to heal.[29,30] Meniscal tissue can heal within the red zone, largely by fibrochondrocytes and fibroblasts that reintegrate and reinforce debrided areas. In the white zone, ingrowth of fibrochondrocytes, fibroblasts, and other synovial cells are limited in their ability to travel into and repopulate the central meniscal region. If we assume that white zone meniscal tissue will remain essentially as debrided, it seems relevant then to produce a stable, smooth rim of tissue that has optimal cell viability and metabolic activity. In this regard, no significant difference was observed when using a wand, basket punch, or a shaver, implying that they should at least be able to produce similar clinical outcomes. Mechanical shavers have had some success in meniscal debridement in decreasing symptoms, but the complications of iatrogenic cartilage injury, a slightly roughened, less contoured surface, difficulty with precise cutting in difficult operative areas, and possibly "overdebridement" are all reasons to further define an alternative method. RF energy may be one such method. Despite some evidence in support of monopolar RF meniscal debridement, bipolar RF energy may be of equal or greater benefit. In fact, while both may have some ability to penetrate meniscal tissue and stabilize a tear, the margin of error for meniscal debridement with monopolar RF energy is small and, as suggested, the need to increase parameters during debridement (such as wand power, contact times) would likely produce profoundly negative effects on underlying cartilage surfaces.[21]

Cell death and metabolic activity in different RF energy-debrided menisci has not been reported. Unlike studies that attempt to define the depth of penetration of RF monopolar and bipolar devices with specific gram loads and contact times, we have taken a different approach. We have attempted to recreate the clinical setting, then quickly quantify and characterize injury as would occur in vivo during arthroscopy. It is apparent that some inherent variability does exist. However, experiments in this study were performed on fresh calf menisci immediately after harvest from the knee, within 24 hours of death, subsequently performing microscopic analyses on the same day as experimentation. As mentioned, analysis is at a cellular level using confocal laser microscopy and sulfate incorporation assay, rather than at the histologic level. These are among some of the strengths of the current study. Treatment goals of meniscal debridement include taking as little meniscus as possible and leaving as smooth and functional a surface as possible, especially since subsequent degenerative joint changes are directly proportional to the extent of meniscus debrided.[31-33]

One weakness of this study is the use of only 1 RF wand device on 1 power setting. Another weakness is the removal of the femoral condyle to gain better access to the meniscus and tibial plateau. In trying to assimilate information and make it as equivalent to the in vivo setting as possible, 1 surgeon performed all of the debridements by hand in a manner consistent with his clinical experience. The fact that 1 device was used, from 1 company and at the same power, is a part of the overall experimental design and study-size constraints. It could be argued that, because of the variability within groups, we could have missed regions of cell death or altered metabolic activity after wand treatments. Through careful study design, meticulous gross and laser microscopy assessments, and by harvesting samples of meniscus and cartilage specifically at the debridement sites, we believe the conclusions of this study accurately represent data on a variety of

modalities on articular cartilage as well as menisci. Studies that compare clinical outcomes of debridement with an RF wand versus a mechanical shaver are needed to determine if short and long-term patient function is significantly different with RF wand treatments.

CONCLUSIONS

Debridement of menisci with a bipolar RF wand, as may occur during arthroscopy, appears to produce levels of cell injury and death similar to debridement with a mechanical shaver. It did not harm underlying articular surfaces, and appears to produce a precise cut and meniscal surface.

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