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Klinik Çalışma - Araştırma / *Original Article*

Histopathological and Biochemical Examinations of the Effects of Bipolar Electrocauter and Quantum Energy Surgical Device Both of Which are Thermal Affected Surgical Devices on Rabbit Liver

Termal Etkili İki Cerrahi Cihaz Olan Bipolar Elektrokoter ve Quantum Energy Surgical Device'ın Tavşan Karaciğerine Etkilerinin Histopatolojik ve Biyokimyasal Olarak İncelenmesi

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Objectives: Quantum Energy Surgical Device (QESD) is a recent thermal working surgical device which works with the principle of tissue application of highly quantum-energized argon gas atoms that are transformed into plasma by employing kinetic energy. In this study, we aimed to examine the operation periods, hemostasis and histological changes on the cutting surface, and the free radicals that can be formed during this period in the partial hepatectomies performed with QESD and bipolar electrocautery (BEC).

Patients and Methods: Partial hepatectomies were performed with BEC and with QESD on 10 rabbits each. Obtained materials during the operation (acute-term group) and 7 days after the operation (short-term group) were prepared for light microscopy, electron microscopy and measurements of free radicals.

Results: In the operations with QESD, hemorrhage was found to be much less and the operation procedures were determined to be accomplished in a much shorter time in comparison with BEC. In the histopathological examinations, while various changes were determined on the cutting surfaces of both groups with regard to thermal trauma, the superiority of QESD drew attention regarding hemostasis activities, damage formed and amelioration periods. Free radicals were determined to be formed less in QESD operations.

Conclusion: The conclusions indicate that QESD method is superior to BEC method with respect to total operation period, hemostasis efficiency and wound amelioration. It is revealed that the free radicals are within acceptable levels in both devices.

Key words: Quantum energy surgical device (QESD); electrocautery; partial hepatectomy; histopathology; ultrastructure; free radicals.

Amaç: Quantum Energy Surgical Device (QESD) kinetik enerji verilerek plazma haline dönüştürülen yüksek kuantum enerjili argon gazı atomlarının dokulara uygulanması prensibi ile çalışan yeni bir termal cerrahi cihazdır. Bu çalışmada tavşan karaciğerinde QESD ve bipolar elektrokoter (BEC) ile yapılan kısmi hepatektomilerde toplam ameliyat süresi, hemostaz, kesit yüzeyindeki histolojik değişimler ve bu süreçte oluşabilecek serbest radikallerin incelenmesi amaçlandı.

Hastalar ve Yöntemler: Onar tavşanda BEC ve QESD ile kısmi hepatektomi yapıldı. Ameliyat anında (akut grup) ve ameliyattan 7 gün sonrası (kısa süre grup) elde edilen materyaller ışık mikroskopisi ve elektron mikroskopisi için ve serbest radikallerin ölçümleri için hazırlandı.

Bulgular: QESD ile yapılan uygulamalarda BEC'e kıyasla kanamanın çok daha az olduğu ve operatif prosedürlerin daha kısa sürede tamamlandığı saptanmıştır. Histopatolojik incelemelerde kesit yüzeylerinde her iki grupta da termal travmayla ilişkin farklı değişiklikler saptanmakla birlikte, hemostaz etkinliği yönünden ve oluşan hasar bakımından ve yara iyileşmesi bakımından QESD'in üstünlüğü ortaya çıkmıştır. Serbest radikallerin QESD'de daha az oluştuğu görülmüştür.

Sonuç: Bu sonuçlar QESD'in operasyon süresi, hemostaz etkinliği ve yara iyileşmesi bakımından BEC'e kıyasla daha üstün olduğunu ortaya koymuştur. Serbest radikallerin her iki cihazda da kabul edilebilir düzeyde olduğu görülmüştür.

Anahtar sözcükler: Quantum energy surgical device (QESD); elektrokoter; kısmi hepatektomi; histopatoloji; ultrastrüktür; serbest radikaller.

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Electrocauters are widely used in surgeries since they are utilized in the coagulation process in addition to cutting. Tungsten, which is a semiconductive metal, provides alternative current to heat resistance in bipolar electocauters and it cauterizes the metal structures that have grown warm. Although it is a safe technique as a coagulator, some problems occur when it is used as a cutting tool. In particular, it adheres to the forceps and the carbonized clot left on the surface of the tissue and the dead tissue cause problems.[1-4]

The basic principle of producing plasma by energizing the argon atoms was first used in the "plasma scalpel" (PS). Argon gas, which is exposed to direct current, creates plasma that has a temperature of 3000 °C. A small plasma jet is formed at the end of the hand piece. However, neither the quantum energy of the gas atoms is controlled, nor total energies of the gas atoms are minimized in the PS. Though, it has been successfully used in surgeries that do not require high precision.[5-13]

The most recently developed tool that works using the plasma technique is the Quantum Energy Surgical Device (QESD). This tool is a thermal blade using quantum energy to do sterilization, coagulation, cutting and evaporation all at the same time. This tool produces high energized argon gas atoms in a closed area called "plasma cell" and these atoms are applied to the living tissue with a canal at the end of the hand-piece. The tool can produce approximately 2000-35000 °K temperatures per atom. In the processes where coagulation is aimed, temperatures lower than 5000 °K per atom are considered to be adequate for the evaporation of the water molecules, but not enough to cut the structural molecular chains of the tissue. In order to perform cutting and tissue evaporation by using the QESD, the energy level used according to the characteristics of the tissue is controlled with a mechanism and it can be increased in line with the aim.[14]

In this experimental study, it was aimed to compare the reliability and efficiency of the QESD which is a new tool that works using thermal effect, with the BEC which is a well-known classic thermal method.

PATIENTS AND METHODS

The study was conducted in İstanbul University, Faculty of Veterinary Medicine, Department of Surgery Lab on 20 rabbits (Oryctolagus cuniculus) with the same age and weighed between 1750-2000 gr obtained from İstanbul University, Institute of Experimental Medicine Research (DETAM), with the approval of the ethics committee.

Ten rabbits were chosen for the BEC operations, and 10 for the QESD operations. The materials obtained right after the partial hepatectomy were named as "acute-term group" and the materials obtained from the same group of animals 7 days following the operation were named as "short-term group" and they were evaluated histopathologically and biochemically. Since one animal from the BEC group died 1 day after the operation, the short-term group had only 9 samples in the rest of the study. One rabbit taken from the BEC and one from the QESD groups were again examined histopathologically after 15 days, 30 days and 6 months following the operation. Biological samples were taken from all rabbits without killing them and they were all healthy when they were set free. The rabbits were anesthetized with intramuscular injection of 100 mg/kg ketamine hydrochloride (Ketalar, Parke-Davis, Eczacıbaşı, Turkey) a few minutes following the intramuscular injection of 10 mg/kg xylazine (Rompun, Bayer, Leverkusen, Germany) and they were allowed spontaneous breathing. A middle line laparotomy was done under sterile conditions and 3 cm^3 resections were applied with the BEC and the QESD operations on the right lateral lobe of the liver. After the 2 cm^3 liver tissue was washed by using physiological saline solution, the acute group was kept under -700 °C in deep freezer for the analysis of tissue free radicals. The samples taken from the rest of the liver tissue were fixed in 10% paraformaldehyde and were prepared for light microscopic examinations. In order to observe the short-term activities, the same operations were repeated for all groups after 7 days

and tissue and blood samples were taken. Tissue samples of two animals from each group were postfixed in 1% osmiumtetraoxide for one hour following an 3h prefixation in 4% glutaraldehyde (0.1 M, pH, 7.2), then they were dehydrated in alcohol series, embedded in Epon 812, and cut. Thin sections were contrasted with uranyl acetate and lead citrate. The sections were examined under Transmission Electron Microscope (TEM), Jeol Jem 1010 (Tokyo, Japan).

After the operations, each rabbit was intramuscularly injected 20 mg/kg penicillin G benzathine (Penedur-LA, Wyeth) for 3 days. The rabbits were followed after for 6 months and it was observed that all were healthy.

In this study, Martin-Electrotom 60 (Tutlingen-Germany) bipolar electrocauter was used. The power of the BEC was 30 watt and cutting forceps were used. The Quantum Energy Surgical Device (QESD) used in our study was developed in İstanbul Technical University, İTÜ-KOSGEB technology development center (Patent filed in the United States Patent and Trademark Office on October 12, 2000 with the serial number: 09/689.216). The power of the device was calibrated as 200-300 watt during the liver resection process and the size of the handpiece was 14 mm.

The free radicals that can be formed in the acute-term and short-term groups as a result of the operations with the BEC and the QESD methods were evaluated by measuring superoxide dismutase (SOD) and glutathione peroxidase (GSHPx) as indicators of antioxidant enzyme activities and malondialdehyde (MDA) as an indicator of the lipid peroxidation activity that shows the membrane damage.

The GSHPx activity was measured using RANSEL (Randox Laboratories Ltd., Co. Antrim, Ireland)[15] test kit and SOD with RANSOD test kit (Randox Laboratories),[16] and MDA concentration was measured according to Ohkawa et al.[17]

Statistical analysis on the measurement values obtained by biochemical analysis were done by using Mann-Whitney U test for the comparison of the groups and Wilcoxon signed-rank test was used for in-group comparisons.

RESULTS

Macroscopic results

When the surfaces of the tissues left after operations performed with the BEC and the QESD methods were examined, a great amount of carbonizing was observed accumulated on the liver surface cut with the BEC. When the incision surface of the resected part of the liver was cut vertically with scalpel, thickness of the damaged tissue was observed to be as 2-3 mm. However, in the case of the QESD method, tissue surface was smooth and there was little carbonized accumulation. Thickness of the damage was observed to be a little less than 1 mm when the resected tissue was cut vertical to the incision surface.

Stoppage of bleeding during resection: In order to stop the oozing blood from the vessels during cutting process in operations with the BEC, the energy level of the device had to be reduced, and hemostasis had to be done on each bleeding point by using hemostatic piece. However, since hemostatis was also done at the same time during resection process with the QESD, the operation was performed without delays. Also in situations when bleeding went on, the power of the device was reduced (25-30 watt) and hemostasis was easily achieved. When total period of the operation is considered, the one with the QESD lasted too short, as about 45 minutes including the laparotomy. On the other hand, operations with the BEC lasted more than 60 minutes depending on the number of bleedings.

Morphological findings

As a result of the light microscopic examinations of the materials obtained from the resected liver parts in the BEC and QESD operations; it was observed that the tissue incision surface was very rough in the BEC, and it was covered with a thick carbonizing layer full of a great amount of damaged cell fragments. The tissue layer of undamaged cells was about 3.2 mm below the surface.

On the other hand, in the QESD operations, tissue incision surface was observed to be relatively more smooth than the BEC, there were no tissue tears, very few broken cell fragments were found, and the carbonizing layer was quite thin (about 0.14 mm). Under this layer, a connection disturbance (cyst-like; according to Perk et al.[19]) was observed in a few lines of cells, as about 0.15 mm. The rest of the cells were in a regular order forming tissue integrity (Fig. 1a). In the light microscopy examinations of the liver tissue preparations obtained from short-term reoperations of the BEC and QESD groups; leukocyte infiltrations were observed in both groups, though it was more in the BEC. In the BEC group, leukocytes were seen in dense groups in closer parts of the incision surface, and they were in big amounts forming small groups in deeper parts. However, leukocyte infiltration was seen mostly in closer parts of the incision surface in the QESD groups, and less in amount compared to the BEC. It was rarely seen in deep layers of the tissue and in single formations since they were not enough in number to form groups, and the cyst-like structures were reduced (Fig. 1b).

It was seen that the view in the short-term group operated with the BEC was available on the 15th day, on the other hand, in the group operated with the QESD, all these changes quickly returned to normalcy, and the degree of leukocyte infiltration lessened though it continued. It was also observed that the cells were hypertrophied, and the number of the binuclear cells increased. The regenerative mitosis was found to be increased in both groups. The chronic view in the BEC became lessened on the 30th day, but still went on; however in the QESD, organ walls became normal and leukocyte infiltration disappeared and returned to normalcy. Six months later, organs looked normal anatomically in both groups. The incision surface was surrounded with a very thin fibrosis tissue and the other findings demonstrated no postoperative signs.

TEM results

In the light microscopic examination of the semithin slides of the acute-term group of the liver tissue resected with the BEC, there was a thick dead tissue layer belonging to cell fragments that were destroyed by burning. There were no cellular structures. Thus, it was found unnecessary to examine ultrastructurally.

In the ultrastructural examination of the acute-term group of the liver tissue resected with the QESD, dystrophic, destructive, degenerative and necrotic changes localized in the cytoplasm of the hepatocytes were observed. These changes displayed that the cell membranes were

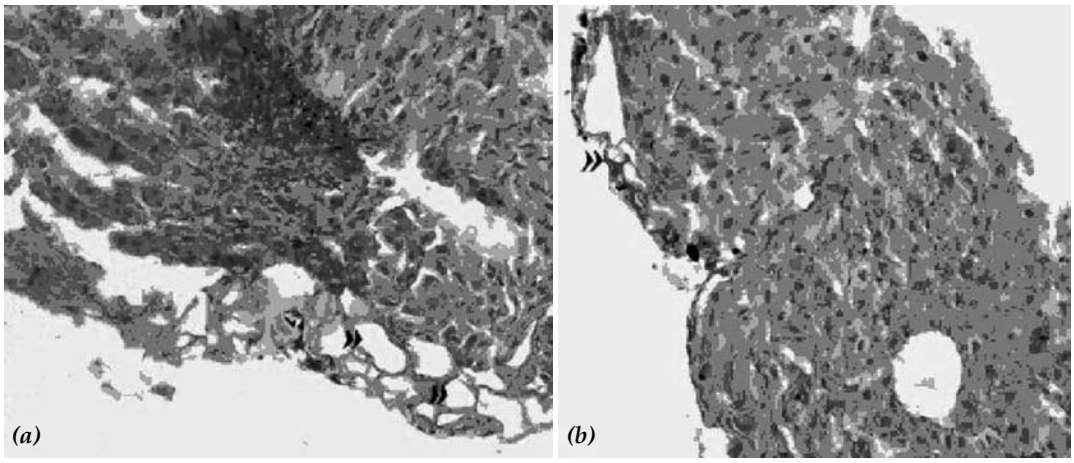

Fig. 1. ***(a)*** *Micrograph obtained from the resected liver parts with the QESD in the acute-term group. Some cell-like fragments left behind after the resection on the incision surface, cyst-like structures right under the surface and normal looking deeper cells are observed. H-E x 200.* ***(b)*** *Liver micrograph operated with the QESD in the short-term group. It is seen that many of the cyst-like structures are resorbed, and the cells are in normal integration. H-E x 200.*

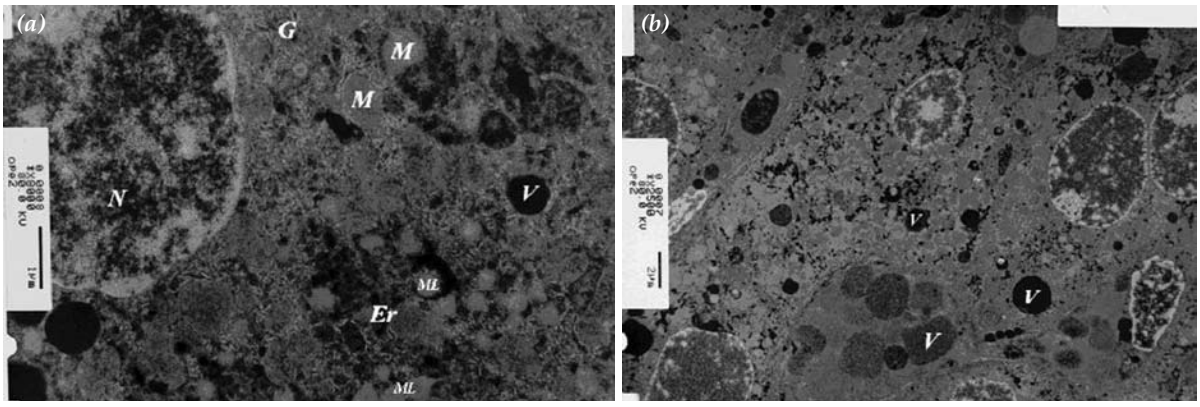

Fig. 2. *Degenerative and necrotic changes are observed in the cytoplasm of the hepatocytes. It is also seen that endoplasmic reticulum channels are widened and they became vacuoles (V) in some areas. On the other hand, disintegration and breaking of the endoplasmic reticulum (Er) are observed in some areas. Mallory materials (M1) are seen in necrotic areas. The homogenization and breaking of mitochondria (M) are monitored. Golgi (G), nucleus (N). H-E x 12 000.*

damaged and cell hydration increased (Fig. 2a, b). Additionally, macromolecular changes were seen in the intercellular area.

In the ultrastructural examination of the short-term group of the liver tissue resected with the QESD operation, dense intracellular reparative regeneration activity was observed; there were fibroblasts, fibrocytes and collagen fibrils though not many. Mitosis in hypertrophic hepatocytes, increase in the number of nucleuses, hyperplasia and proliferation of the organelles were detected (Fig. 3a, b, c).

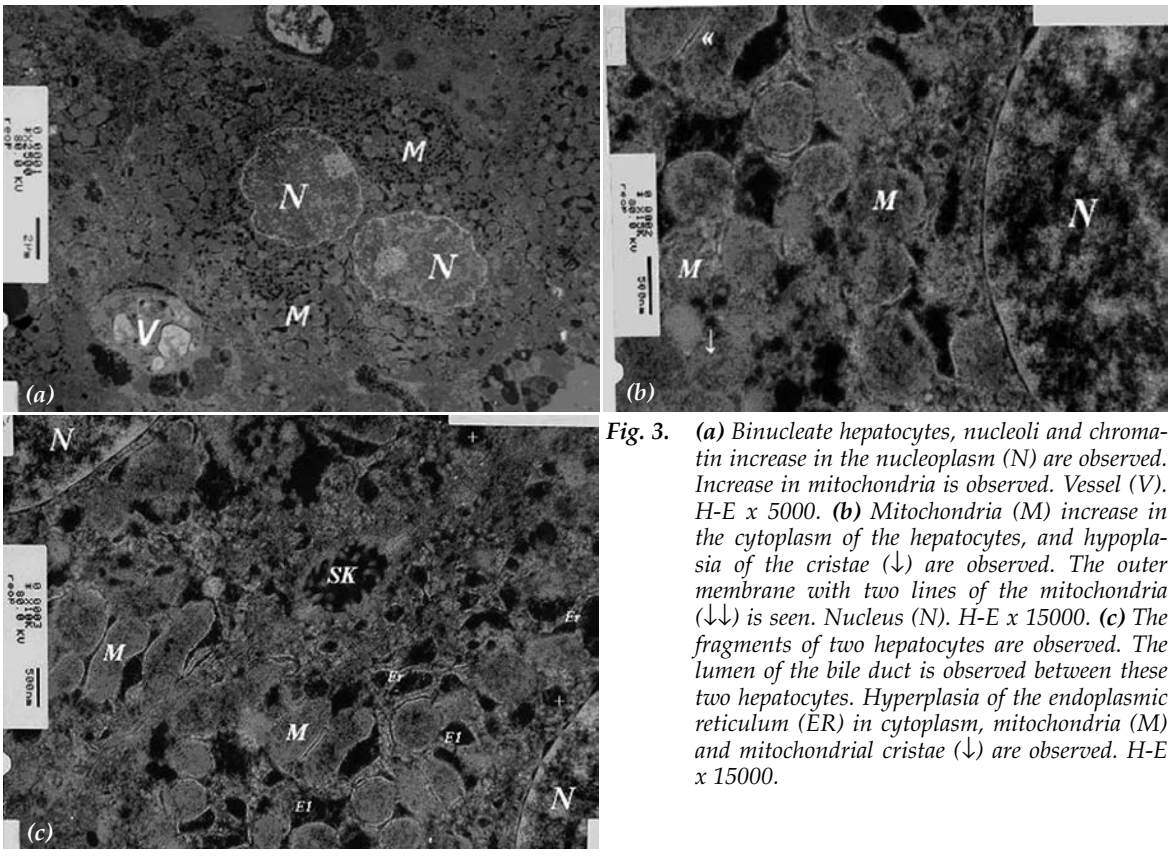

Fig. 3. ***(a)*** *Binucleate hepatocytes, nucleoli and chromatin increase in the nucleoplasm (N) are observed. Increase in mitochondria is observed. Vessel (V). H-E x 5000.* ***(b)*** *Mitochondria (M) increase in the cytoplasm of the hepatocytes, and hypoplasia of the cristae (↓) are observed. The outer membrane with two lines of the mitochondria (↓↓) is seen. Nucleus (N). H-E x 15000.* ***(c)*** *The fragments of two hepatocytes are observed. The lumen of the bile duct is observed between these two hepatocytes. Hyperplasia of the endoplasmic reticulum (ER) in cytoplasm, mitochondria (M) and mitochondrial cristae (↓) are observed. H-E x 15000.*

Table 1: Statistical analysis results of the data gathered from the rabbits to which partial hepatectomy was applied with the BEC and QESD methods

Variables	Units	Groups		N	X ± SD	*p*
Plasma MDA	nmol/ml	acute-term	cautery	10	3.35 ± 0.972	p<0.05*
			APS	10	2.48 ± 0.855	
		short-term	cautery	9	3.23 ± 0.442	p<0.05*
			APS	10	2.56 ± 0.518	
Tissue MDA	U/mg	acute-term	cautery	10	6.92 ± 4.688	p>0.05
			APS	10	5.24 ± 3.394	
		short-term	cautery	9	6.33 ± 2.705	p<0.05*
			APS	10	2.84 ± 1.642	
Erythrocyte SOD	U/gHb	acute-term	cautery	10	4191.74 ± 5311.27	p>0.05
			APS	10	2241.93 ± 1961.0	
		short-term	cautery	9	4013.50 ± 7343.61	p>0.05
			APS	10	1852.09 ± 1300.79	
Tissue SOD	nmol/ml	acute-term	cautery	10	5.88 ± 3.543	p>0.05
			APS	10	6.28 ± 2.476	
		short-term	cautery	9	5.74 ± 2.556	p>0.05
			APS	10	4.55 ± 1.687	
Total blood GSHPx	U/gHb	acute-term	cautery	10	201.38 ± 152.062	p>0.05
			APS	10	177.33 ± 112.384	
		short-term	cautery	9	116.68 ± 79.112	p>0.05
			APS	10	122.056 ± 63.393	
Tissue GSHPx	U/ mg	acute-term	cautery	10	1.43 ± 0.496	p>0.05
			APS	10	2.71 ± 3.892	
		short-term	cautery	9	0.76 ± 0.909	p>0.05
			APS	10	2.71 ± 5.242	

Free radicals

Total results of the statistical analyses are shown in Table 1. As it is seen in Table 1; there is a statistical difference between the BEC and QESD groups in short-term tissue MDA, and in acute-term and short-term plasma MDA as a result of the comparisons between groups done with Mann-Whitney U test ($p<0.05$). There is no statistical difference in the others. Also no significant difference was found between the acute-term and short-term as a result of Wilcoxon signed-rank test used for the in-group comparisons ($p>0.05$).

DISCUSSION

Electrocautery methods are successfully used in addition to a great many of surgical methods (ultrasonic dissectors, hydrojets, lasers, etc.) having a specified goal of cutting and coagulation in parenchymatous tissues like liver. In the bipolar electrocauteries, a low-conductive and high-temperature resistant metal such as tungsten is heated by applying an alternative current with two poles. This heated metal works via cauterizing the tissue. Current intensity and metallic mass can be increased as much as required since current transmission from the patient is out of question. Therefore, the high temperature energy obtained can be used to cut the tissues; coagulation is also able to be done by reducing the energy level. However, there may be too much damaged area left after resection operation. Moreover, the metal structure touching the tissue during the operation causes tissue adherence risk.[1-4]

Plasma scalpels in early use employed ordi-

nary direct current (DC) voltage, which permitted control neither for the ionization nor the total energy of the atoms applied per second. The disadvantage of those devices was that total energy consisting of high thermal risks could not be kept as low as it was necessary. Furthermore, as gas transmission could not be diminished during the formation of plasma, blow-effect was seen. It means expelling a great amount of gas atoms onto the tissue, which mechanically destroys the tissues around the operative site. As a result, plasma scalpels caused high necrosis in the tissue to which they were applied because not only total energy and gas transmission were uncontrollable but also blow-effect was seen. Besides, there are only a few operation trial samples to which this equipment has already been applied.[5,6,8-13,18]

In the case of the QESD, total energy can be obtained in desired levels. Therefore, with the choice of optimum quantum energies, acceptable minimum necrosis will occur for the processes of surface sterilization, coagulation, incision and evaporation. Recently, Elmacı et al.[14] have elaborately defined the work principle and technical features of the QESD, which is the most recent device working through plasma technology. With the decrease in total electric energy, it is possible to minimize the amount of gas blow from the end of the handpiece synchronously and so blow-effect is rarely seen in the tissues applied. And with the diminution in blow-effect, the damage caused by the mechanical effect of the blowing pressure around the application site will minimize. Therefore, the necrosed tissue to be formed will be at acceptable levels.

When a lot of argon atoms with high energy are applied to the tissue, they transfer their energies by crashing the first atoms, molecules and biomolecules they come across. The transferred energy is at a level that will evaporate them. When a cluster of high energized atoms is applied onto the bleeding area in order to achieve hemostasis, the air current in front of the cluster removes the blood pool by blowing (here blowing speed is only as much as the fluid is moved) and when the atoms with high energy reach the main tissue, they evaporate the upper molecules of the tissue while they provide coagulation by binding the molecules below them. Since the process is completed via atoms with high energy in a very short period of time, the damage caused to the peripheral tissues is at minimum level. And the coagulated devitalized layer formed is enough to cease bleeding. When argon gas cluster is applied onto the tissue on a line by adjusting the energy level of the device as necessary, the tissue can be cut through linear evaporation. Required energy level varies according to the tissue to which cutting process will be applied. Hemorrhage does not occur during this resection process too.

As a matter of fact, in the morphological studies, total thickness of destroyed cell fragments and the coagulated layer was found to be as about 0.1 mm and below them a cyst-like layer of varied thicknesses was observed. Since Perk et al.[19] thought that the cyst-like layer which they found as approximately 0.7 mm would necrose soon, they evaluated it within total thermal damage and they recorded the total damage as 0.28 mm. However, according to our short-term findings, although amelioration period is very short, since a crucial part of these structures is resorbed and turns into the appearance of normal tissue and the rest is seen to be lessened, it must not be evaluated within devitalized tissue (Fig. 1b). Therefore, it is necessary to regard the thickness of the necrosed tissue as 0.1 mm. In addition, this result is even lower than the value of 0.2-0.3 mm obtained by Nechaĭ et al.[9] by using plasma scalpel. Lots of parameters such as the power of the device during the application, the application period and the concentration of electrolytes existing in the tissue fluid at that time are the efficients of the varied thicknesses of devitalized layer in the BEC method. Thus, when the layer formed of cells in variable thicknesses that are thought to result in necrosis for certain is also considered, the 2-3 mm value obtained is incomparably higher than the values obtained with the QESD. The reason of that is the effect of mass energy transferred from the device on the thickly layer below and around the operation area. The fact that no literature has been found about the thickness of the layer

other than the 0.26 mm at average found by Perk et al.[19] is because this value is quite unsteady depending on those parameters. It is quite possible that Perk et al. did not take the layers that would result in necrosis in time into account.

The occurrence of cyst-like structures. High energized argon atoms ionize the substances they first crash and cause them to break up by transferring energy to them; and the arising ions are mixed into the air. And some of these ions may be assumed to be mixed into the tissue liquid. The ions mixed into the cells and the intercellular liquid will then cause the homeostasis to disturb in the periphery of the operation area. The expansion of the damage is going to be prevented around the damaged area by breaking down the connections between nexuses, which enable the intercellular metabolite transfer between cells especially in the ones that have high performance like the liver parenchyma cells, myocardial cells, etc. Cyst-like structures could be formed in this way. In fact, macromolecular changes, which are the results of the breakdown of the intercellular structure we observed in our ultrastructural findings, may be considered to point out this.

During the development of the prototype of the device, some of the researchers from our team attended the animal experiments (Project No: TÜAF 197). In these experiments, the device was successfully applied to all tissues from the loosest to the most compact ones such as bone tissue. A great mass of tissues can be evaporated by applying the argon jet on a particular area for a long time when the device is used in high energy levels. In this way the undesired tissues like the cancer may be destroyed via evaporation. In the operations for cancer masses, the biggest fear of all surgeons is the occurrence of metastasis due to inadequate hemostasis. The QESD seems to be a brilliant method to prevent metastasis by safely guarantying the hemostasis of the vessels around the operation area and preventing blood cease during cutting and evaporation processes (V. Dolenc, in comment: 14). It is also possible to do this process using high energetic laser. However, depth control is difficult in high energetic laser. Moreover laser rays may damage the biomolecules around the point focused for the operation. The damage that may occur in the DNA may cause more serious results in the future compared to the damage in other biomolecules. In the QESD operations, such risks are almost never observed. Quantum energy directly affects the first cellular structure elements met on the surface. As these cellular structure elements are removed, it affects the coming elements.

Being able to calibrate the atomic energy will make it possible to make very little handpieces for micro-surgery[14] and to do endoscopic practices.

Ultra-structural findings gained from the QESD operations displayed that the membrane structures in the hepatocytes were ruined in the QESD acute-term and they were exposed to hydratation. The riven cellular membrane fragments right on the cutting surface and partial membrane damages in the cells under the cutting surface resulted from the working principles of the QESD mentioned above. That there is no membrane damage in the deeper cells displays this.

There were compensatory regeneration and regenerative regeneration findings in the ultrastructural examination of the short-term operations. Thus, structural disturbances due to organ damage are going to be rarely observed.

Wound healing is observed to be as complete regeneration with primary wound healing or incomplete regeneration with secondary would healing.[20] That there is almost no bleeding in the QESD operations causes a decrease in the number of macrophages seen in the damaged area. As a result, there is only a little formation of the connective tissue (histiocyte fibroblast, collagen). Wound healing is seen in the form of primary wound healing and scar tissue does not come into being. However, in the BEC findings, leukocyte infiltrations in masses were seen. Primary or secondary wound healing is possible depending on the size of the damage.

As it is seen from our findings related to the free radicals in Table 1, in the MDA measure-

ment results of plasma and tissue, decrease is present in the group operated with the QESD compared to the group operated with the BEC; in addition, while there is almost no change in the plasma MDA level in the group operated with the QESD, in tissue MDA level a significant ($p<0.05$) decrease was observed in short-term compared to the acute-term. The MDA, which is one of the end products of lipid peroxydation, may be accepted as an indicator of membrane damage.[17] We can say that there is less membrane damage in the operations done with the QESD compared to the operations done with electrocautery, and this result is very important in order for the regeneration to be completed in a short time. The explanation of this fact lies beneath the effect mechanism of the QESD. Gas atoms with high quantum energy affect the first cellular structures they crash and make them evaporated. A great part of the cellular structures is formed of cell membranes. All of these structures will be broken with high energy and evaporated. The rest are just the cellular fragments, which are broken at the stoppage of cutting process but have not completed the evaporation process. According to the morphologic observations, the amount of these fragments is at the level of microns. However, cellular elements formed as the end products of breaking are remained in electrocautery since the device could not produce enough energy to evaporate. During morphologic observations, the thickness of the layer formed by the accumulation of artifacts was found to be 2-3 mm. A great amount of the remained artifacts would belong to broken but not evaporated cellular membranes.

The fact that the results of MDA measures of short-term tissues were found to be rather less compared to acute-term results in the group operated with the QESD showed that the amount of damaged membranes remarkably decreased owing to regeneration during this period. When the same comparisons were done on the cautery operation results, it was found that the level of lipid peroxydation was still high though it partially diminished at the end of this period, and this showed that regeneration still progressed in high levels. This was also verified by morphologic observations.

When SOD and GSHPx results that can be regarded as an indicator of free oxygen radicals are considered, no statistically significant difference was found in inter-group and inner-group comparisons but this does not mean that free radicals are not formed during the running of these devices. Electrocauteries cannot function without ionization. The equivalent temperature of electrons was calculated as 105 000 °K. Individual electrons and ions are possible to be formed at high temperatures above 100 000 °K. The energy involved in only one carbon-carbon covalent bound is 348 kj/mol at average.[21] It was calculated that this bound can be broken at 27 000 °K.[22,23] As a result, biomolecules involving carbon chains could be broken into atoms, ions and a lot of small molecules in the tissues. There could be free radicals coming out as a result of the breaking of those biomolecules. During this period, air (O, N) molecules would also get ionized. The oxygen of the air that has become ionized could be regarded as a free radical, too. It could be considered that a few but not many free radicals would be formed even during the running of the QESD. The free radicals were formed on the tissue surface to which the device was applied but they gently diffused into the tissue fluids, or were mixed into the air. That can be the reason why no statistically significant difference was found in the measurement results.

However, in the results of erythrocyte SOD and tissue SOD short-term measurements, a gradual decrease drew attention in both the cautery and the QESD compared to the acute-term and the decrease in the QESD was more than it was in the cautery. Similarly it was seen that the decrease in total blood GSHPx short-term was much less in the cautery compared to acute-term while it was a bit more in the QESD. When the tissue GSHPx was considered, it was seen that there was no change between acute-term and short term in the QESD whereas there was a decline in the cautery. It was observed in the morphologic examinations that phagocytic cell infiltration in the cautery group in short-term was more than the one in the QESD group. It is possible that having less decline in measurement values in short-term compared to acute-term in cautery and more decline in the QESD

(even though there is no statistically significant difference) correlates with phagocytic cell infiltration.[24-28]

In conclusion, both cytological and biochemical results made us consider that the QESD is far superior to the BEC in the processes of operation and recovery when two devices running via thermal system are compared with each other. Both methods are considered to be at acceptable limits in terms of free radicals.

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