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Basic histological aspects in arthroscopic laser surgery

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Artroskopik lazer cerrahisinde temel histolojik görünümler

İnsan eklem kıkırdağı ve menisklerinin lokal lazer ışınlarına doku cevabını incelemek için ameliyat ve otopsiden elde edilen örnekler belirli bir lazer ışını ile muamele edildiler. Karşılaştırma için bir UV Excimer-Lazer, bir Argon-ion-Lazeri ve bir Nd: YAG-Lazeri kullanıldı. Uygulama gücü, süresi ve frekans ile sıklığı modifiye edildi.Daha sonra doku özel teknikleri ile hazırlanarak ışık mikroskobunda incelendi ve Excimer-Lazer kullanılarak elektron mikroskobik inceleme yapıldı.

Beklenildiği gibi "termal lazer (Argon-ion-lazer / Nd: YAG Lazer)"in kullanılması büyük doku hasarı oluşturdu. Bu hasar bir kombinizasyon zonu ve enerji artışı ile derinleşen koagülasyon nekrozu şeklinde izlendi. Buna karşın Excimer-Lazer ile sporadik, önemsiz, marjinal doku hasarları oluşuyordu. Işık mikroskobunda kıkırdak ablasyon sınırında nükleusu olan sağlam hücreler izleniyordu. Ek olarak Excimer-Lazer ile hyalin materyeli kaplayarak kıkırdak dokuyu işaretlemek mümkün oluyordu. In vitro araştırmalarımızın sonucu olarak termal lazerlerin artroskopik cerrahisinde yeri olmadığını söyleyebiliriz. Buna karşın Excimer lazer artroskopik cerrahide ek bir cihaz olarak kullanılabilir.

Anahtar kelimeler: *Lazer, artroskopi, kıkırdak, meniskler, histoloji*

In order to investigate the tissue reaction of human articular cartilage and menisci to local application of laser radiation, human articular cartilage harvested in surgery or autopsy, and meniscal tissue were exposed to a determined laser radiation. For comparison an ultraviolet Excimer-Laser, an Argon-Laser and a Nd: YAG-Laser were used. Intensity, duration of exposure, frequency or interval times of radiation were modified.

Afterwards, the tissue by the aid of special preparation techniques was subjected to a lightmicroscopical histological investigation, completed by scanning-electronmicroscopical studies of the cartilage after exposition to an Excimer-Laser irradiation.As expected, the use of so called 'thermal Lasers' (Argon-lon-Laser/ Nd: YAG-Laser) causes large tissue damage as could be seen by a carbonisation border zone as well as by a much deeper coagulation necrosis, the higher energy was which was applied. In contrast, the use of the Excimer-Laser allows a sharp determined tissue ablation only by sporadic unimportant marginal tissue damage. Lightmicroscopically, there were intact cell nuclei seen up to the border of the cartilage ablation channel. Additionally, it seems to be possible to perform some kind of surface sealing of cartilage tissue by wrapping the hyalin structures as seen after Excimer-Laser application.

In conclusion from our in vitro experiments, there is no indication for the employment of so called 'thermal Lasers' in arthroscopic surgery. In comparison, the Excimer-Laser, used under arthroscopic control, is an available additional instrument in arthroscopic joint surgery.

Key words: *Laser, arthroscopy, cartilage, menisci, histology*

Since effective fibres have been developed and the laser beam has therefore been able to be guided only with an acceptable loss of energy through small portals into the joint, employment of laser in arthroscopic surgery, especially of the knee joint, has become of increasing interest. When the cardiothoracic surgeons started to ablate plaques at cardiac valves and in vessles[3], we were interested to know whether the laser could be a useful instrument in arthroscopic surgery as well.So our study was carried out to investigate the tissue reaction of human articular cartilage and menisci to local laser irradiation. Also we wanted to find out which laser system allows the use of flexible fibres was the most suitable for arthroscopic surgery.

Material and method

During surgery in patients, undergoing total joint arthroplasty, harvested human articular cartilage and menisci explanted in operations autopsy were submitted to a focal laser irradiation (Figur I).

In comparison, a 1064 nm Nd: YAG-Laser, an Ar-

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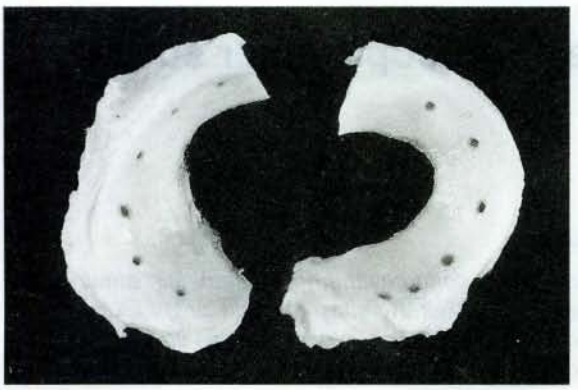


Figurs I: Human menisci after focal Excimer-Laser irradiation

gon-Laser with a wavelength between 488 and 512 nm and a 308 nm ultrauiolet Excimer-Laser were used. The Nd: YAG-Laser worked in a continuous wave mode. The Argon-Ion-Laser worked in a so called chopped mode, resembling the pulsed Excimer-Laser. Intensity, duration of exposure, frequeney or interval times of the radiation were changed as shown in the correspondent diagrams (Figurs II - V).

time of irradiation (in sec.)	Watt	Joule
1, 0	53 - 79	53 - 79
1, 5	49 - 75	73, 5 - 112, 5
2, 0	72 - 74	144 - 148
4, 0	40	160

Figurs II: Nd: YAG-Laser Irradiation / Meniscus

Watt	Pulse duration with an interval time of 0.1 sec					
	0.02	0.04	0.10	0.20	0.50	1.00 sec
	duration of exposure					
5	3	3	5	4	4	3 sec
10	15	15	15	5	3	2 sec

Fig III : Argon- Laser Irradiation / Meniscus (focal irradiation)

pulse rep. rate	energy	duration of exposure
10 Hz	20, 40 mJ	5, 10, 15 sec
	50 mJ	5 sec
20 Hz	40 mJ	5, 10, 15 sec
40	30, 40 mJ	5, 10, 15 sec
	40 mJ	5, 10, 15 sec
120 Hz	10, 20, mJ	5 sec
	30 mJ	5, 10, 15 sec
	40 mJ	2, 4, 4 sec

Figur IV: Excimer-Laser Irradiation (308 nm) / Meniscus (focal irradiation)

The laser beam was guided through a flexible quartz fibre with a diameter of 0. 6 mm. In one series of the irradiation of human articular cartilage a 9 french multifibre with a diameter of 3. 3 mm was used. Several special preparation techniques were used to subject the tissue to lightmicroscopical histological investigation, as there were embedding in paraffin or resin, stepping into sections and staining with HE, Alcianblue or in Ladewig. Complementarily the depth of the ablation channels was measured.

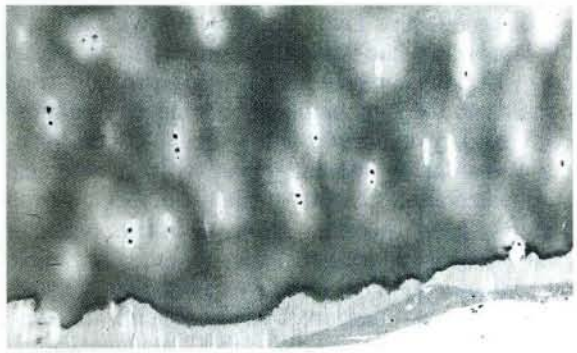
pulse rep. rate / energy	20 Hz	40 Hz
	duration of exposure	
10 mJ	20 sec 15 sec 5 sec	30 sec 15 sec 5 sec
18 mJ	15 sec 5 sec	15 sec 5 sec

Figurs V: Excimer-Laser Irradiation (308 nm) /Hyaline cartilage (Quartzfibre 0, 6mm)

Results

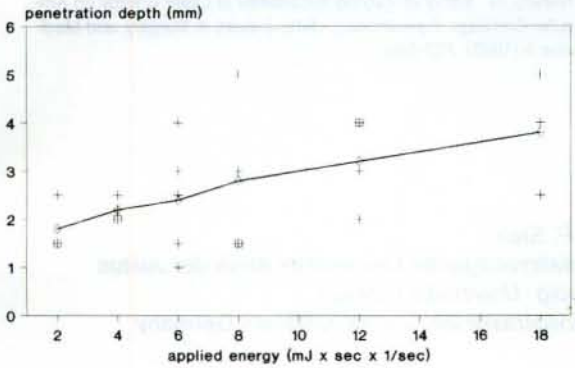
The use of the Nd: YAG-Laser as well as the use of the Argon-Ion-Laser causes large tissue damage as could be seen by a carbonisation border zone as well as by a much deeper necrosis, the higher the energy was applied (5).

The duration of interval times to cool down in relation to the pulse duration was proportional to the extent of tissue damage. Especially the ablation of articular cartilage showed distinct destruction of the surface. In contrast, the use of the Excimer-Laser allows a sharp, determined, very well controlled tissue ablation only by sporadic unimportant marginal tissue damage (1). Lightmicroscopically, there were intact cell nuclei seen, up to the border of the cartilage ablation channel (Figur VI).



Figur VI: HE stained articular after Excimer-Laser irradiation. There are lightmicroscopically intact cell nuclei seen up to the sharp determined borderline of the ablation channel

The ablation rate seemed to be linear in proportion to the utilized energy is concerned (Figur VII).



Figur VII: Excimer-Laser / Meniscus

The surface of the cartilage revealed a smooth hyaline structure after local irradiation with the Excimer- Laser.

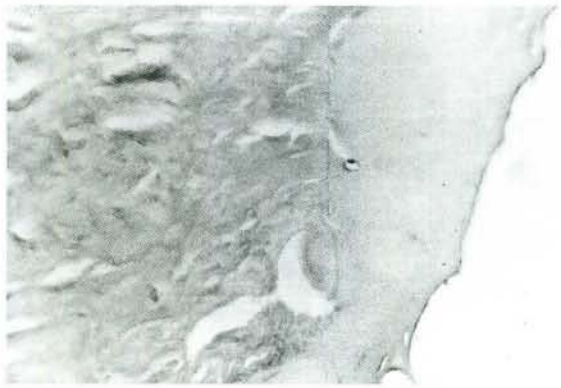
Discussion

In spite of the fact Miller et al. describes the Nd: YAG- Laser as a safe and effective laser in meniscal tissue ablation (2, 4), we observed a very large tissue damage that was merely in an acceptable range when the laser was used with low energy. It is a probable that a pulsed mode or the cooling effect of liquid medium in arthroscopic surgery decreases the depth of damage. Of great importance to decrease the depth of cell destruction is the duration of interval between the single pulses in relation to the applied energy, when using a laser system in a pulsed mode.The same macroscopical and histological results as seen after a Nd: YAG- Laser irradiation were seen after a local application of the Argon- Ion- Laser beam. Only with short pulsed ultraviolet Excimer-Laser it was possible to carry out a controlled ablation of cartilage tissue and menisci without essential cell destruction at the border zone. Also the penetration into bone was possible without a great increase of tissue damage (Figur VIII).

The exceeding variability of measuring data, concerning the depth of the ablation channel after focal irradiations of meniscal tissue, seems to be an effect on the intra-and interindividual varying tissue quality of the menisci. Additionaly, it seems to be possible to perform some kind of surface sealing of the cartilage tissue by wrapping the tissue at its surface (Figur IX).

We cannot answer the question, whether this is a durable effect and may even avoid a progress of cartilage destruction in arthrosis.

Figur VIII: Scanning electronmicroscopial view to human articular cartilage after Excimer-Laser irradiation by of the 9 french multifibre. There is a sharp determined tissue ablation seen and even the penetration into the subchondral bone is possible.



Figur IX: Alcian stained human meniscal cartilage after an Excimer-Laser irradiation. There seems to be some sort of surface sealing possible.

Conclusion

The possibility to guide the laser beam through flexible fibres should be the prerequisite to use lasers in arthroscopic surgery. In conclusion from our in vitro experiments, there is no certain indication for the employment of so called "thermal lasers" with a high wattage because of the important tissue damage.

In comparison, the Excimer-Laser, used under arthroscopic controll, is an available additional instrument in arthroscopic joint surgery that makes a sharp and controllable tissue ablation possible. And in fact, the flexible fibre is a very small instrument which is of great importance in tight joints.

But there are still some risks left, as there is still not answered question of cell mutagenicity or the risk of an uncontrolled tissue destruction if the fibre burns down, that should never be forgotten.

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