The Development of an Endoscopically Applicable Optomechanical Coupler for Laser Induced Shock Wave Lithotripsy (LISL)

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The treatment of urinary stones has been radically changed by the introduction of extracorporeal shock wave lithotripsy. In combination with modern endo-urologic techniques 96% of all urinary stones can be treated without open surgery. Ureteral stones, especially those impacted into the ureteral wall, represent a special therapeutic challenge for the urologist. Currently, treatment consists of ureteroscopy to the stone with ultrasonic or electrohydraulic lithotripsy. The resulting stone fragments can be extracted by wire baskets or forceps. The major set-back of this method is the need of a rigid ureteroscope for instrumental access to the stone and for visual control, necessitating anesthesia and hospitalization. Newest developments in laser medicine provide a method of destroying urinary calculi via flexible fiber systems by use of laser induced shock waves. Shockwave excitation needed to fracture calculi can be achieved in different ways.

| LASER LITHOTRIPSY |
| CLINICAL ASPECTS — TECHNICAL USE |
| coupler systems | applicably fused coupler | spherically polished fiber | optomechanical coupler | bare fiber |
| laser-type | Q-switched Nd : YAG | Dye |
| LIS induction | independent | target facilitated | independent | target released |
| coupler - stone distance | 0 - 6 mm | 4 - 6 mm (1) | 0 - 3 mm | contact |
| fiber - coupler flexibility | ( ) | ++ | + | +++ |
| endoscopy use | nephroscope | ureteroscope | ureteroscope | ureteroscope |
| possible blind application | no (also) | no | yes | no [tissue damage] |

Fig. 1:
Comparison of application systems for LISL

The tunable pulsed dye laser does not require any coupling device. Initial plasma-ignition is achieved by laser-pulse energy absorption on the stone surface. The Q-switched Neodymium:YAG laser requires either a focusing device to accumulate the high power density of approximately 10 gigawatt per square centimeter needed for
spontaneous dielectric breakdown in a liquid medium or an ignition device in form of
an opto-mechanical coupler as first described by YANG /1/ and also by FAIR /2/. The
requirements for a coupler to be used with the Q-switched Neodymium:YAG laser in
clinical application can be summed up to four principles:
1) Laser induced breakdown should be originated reliably with every pulse to avoid
direct tissue irradiation.
2) The power needed to destruct urinary stones of customary size should not cause
any thermal effects.
3) The dimensions and the flexibility of the application system consisting of the
quartz fiber, the coupler and an irrigation system must offer advantages over the
currently employed techniques.
4) The durability of the coupler system must ensure that urinary stones can be
destroyed reliably in one attempt without change of the application system.

Fig. 2: Diagram of a five lens optical coupler (MBB)

Development of such a system was initiated in 1985 by MBB Medizintechnik in
Ottobrunn. In vitro and in vivo assessment was performed at the Urologic Department
of the Medical University Lübeck and the Medical Laser Center Lübeck. The initially
developed coupler system consisted of an optically corrected focusing device of five
lenses held in a brass encasing. The distal end of the coupler is formed to a
spherical mirror to reflect and focus the generated shock waves to the stone. The
outer dimensions of this first focusing system was 4.5 mm with a total rigid length
of 3.5 cm. The energy needed to achieve dielectric breakdown is approximately 10 mJ
per pulse. High repetition rates of 10 to 20 Hz are needed to guarantee rapid stone
disintegration. The durability of this system was limited because evaporation
processes of the brass encasing form thin film layers on the lenses leading to their
destruction. The range of application is severely limited by the dimensions of this
system. Clinical evaluation in two patients by way of percutaneous nephroscopy was
performed showing good results, HOFSTETTER et al /3/, SCHMELLER /4/. This encouraged
the development of a smaller system in combination with a 600 μm fiber. The outer
diameter of this system is 2.8 mm. Laser induced breakdown is achieved with energies
of about 10 mJ/pulse. This system, however, showed even less durability than the
larger optical focusing system, only lasting approximately 100 pulses until one of