THE LUMENIS ULTRAPULSE®
CARBON DIOXIDE LASER TECHNOLOGY: POWER AND VERSATILITY

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INTRODUCTION:

Ablative lasers have been used in dermatologic and aesthetic procedures for more than two decades. The mechanism relies on effects on the tissue through ablation and coagulation using tissue water as chromophore. This article will highlight the key principles of carbon dioxide laser (CO2) focusing in particular on the UltraPulse® technology by Lumenis.

ABLATIVE LASER PHYSICS:

The mid and far infrared wavelengths beyond 2000nm are used in current ablative laser technology as these higher wavelengths target water as chromophore. Currently there are three wavelengths used: 2940nm Erbium:YAG (Er:YAG), 2790nm Yttrium Scandium Gallium Garnet (YSGG), and the 10.600nm CO2 laser. The water absorption affinity is the highest with Er:YAG and lowest with CO2 with the YSGG sitting in between. Work performed by the American laser dermatologist Rox Anderson showed that with the CO2 laser, the tissue requires a minimum ablation threshold energy of 5 joules per cm^2 and ideally in less than one ms (generally considered the thermal relaxation time of the skin) to have an ablation characteristic with minimal collateral thermal damage. The changes to the tissue as a result of the incoming ablative laser beam depend on the tissue temperature reached. A temperature of 100 degree Celsius will lead to "vaporisation" of tissue, clinically observed as ablation. A temperature higher than 150 degrees leads to carbonisation, clinically evident as charring and is an unwanted clinical endpoint. A temperature of around 65 degrees is the desired temperature required for protein denaturation that clinically gives the tightening effect and stimulates the process of new collagen formation. Scientific studies have shown that this temperature gradient observed in the dermis is responsible for a cascade of important molecular pathways mainly through the induction of heat shock proteins that play an important role in collagen remodelling. Understanding the tissue interaction with the CO2 laser is important in determining how to use this laser efficiently. Depending on the clinical goal a practitioner desires to achieve, the ideal setting would be to reach the ablation threshold with a controlled zone of thermal injury for collagen remodelling with minimal to no charring. In other words, optimal safety and efficacy dictates a favourable and consistently reproducible ablation to coagulation ratio.

Images courtesy of Joseph Niamtu III DMD

CO2 – FROM FULL FIELD TO FRACTIONAL:

The CO2 laser in its original non-fractional use was widely considered the gold standard in the treatment of wrinkles and scarring in the 1990s, a process referred to as "full field resurfacing". Though the results were clinically impressive, this was achieved at the cost of prolonged wound healing and downtime. In order to reduce the risk of side-effects with the procedure, the principle of fractional photothermolysis was pioneered. The first concept of the fractional photothermolysis was described in 2003, however it wasn't until a year later when this technology was first introduced in clinical practice with the Lumenis UltraPulse® having the first fractional ablative machine. The technology involves the production of an injury pattern to the skin with "ablated" columns of tissue called microthermal zones (MTZs) with intervening uninvolved areas of skin. In practice this will allow for rapid wound healing through migration of cells from the neighbouring uninvolved areas with less risk of long-term complications. The MTZs vary greatly in their diameter and depth as well as the amount of coagulation around them, referred to as the "coagulative zone". These characteristics are important and one that Lumenis has particularly advanced due to their pulse structure and power. The non-ablative fractional lasers – wavelengths below 2000nm – create non-ablative MTZs and rely on the generated heat in the dermis to stimulate collagen formation. Whilst this technology has certainly been shown to improve on wrinkles and scarring; it is widely accepted that the ablative technology results in superior results. There are numerous studies confirming this fact, including a split-face study using the Lumenis UltraPulse® device. There are currently several CO2 machines in the market and to the novice laser user the key important differences may not be apparent. The differences relate to key principles such as pulse duration, peak power, fluence, handpieces (with or without scanning technology), fractional cover and versatility of applications. The Lumenis UltraPulse® is currently the most powerful CO2 in the market with a maximum power of 240 Watts (W), six times more powerful than most of the other available CO2 machines.

Images courtesy of Dr Jill S. Waibel

PULSE STRUCTURE AND WIDTH:

One of the key core components of success and safety is the UltraPulse® structure mode this machine has. Traditional CO2 machines have either a continuous wave pattern or a "pulsed" pattern. In the majority of CO2 lasers the pulse structure in the pulsed pattern consists of the so-called "superpulse" structure. This means that the pulse has a peak power but tails off at the end of the pulse with some residual unwanted energy that increases the risk of collateral damage. The residual thermal zone is much wider in the continuous mode pulse which is clinically evident in prolonged erythema and a higher complications rate. The UltraPulse® structure that is used in Lumenis differs in that it resembles a top hat profile beam with a rapid peak that does not tail off and therefore has a narrower coagulative zone. The advantage of this technology, coupled with a pulse duration of less than one millisecond (shorter than 0.8ms and made possible due to the high power of the machine), is the excellent ablation to coagulation ratio with minimal charring and unwanted thermal damage. This consistent and predictive ablation to coagulation ratio has been replicated in numerous histological studies. The aforementioned concept of pulse duration (also referred to as dwell time) is of crucial importance. A pulse duration greater than one ms will lead to more of the given energy to be conducted, in other words a lower ablation to coagulation ratio, thus giving rise to a broader zone of thermal damage. A low-powered CO2 machine will have to extend the pulse duration over one ms and use higher energy in order to get a deeper penetration compared to a high-powered CO2 such as Lumenis UltraPulse®; this in turn leads to a greater zone of thermal damage and possible complications.

INCISIONAL HANDPIECES:

The Lumenis UltraPulse® comes with several incisional handpieces in 0.2 and 1.0mm non-collimated and a 2.0mm collimated handpiece, referred to as the "true spot". The power of the machine (240 W) allows for a very rapid and powerful incision which gives a great versatility in surgical procedures, requiring incision and coagulation. In a defocused mode these handpieces allow for a high "power irradiance" that can allow for rapid vaporisation of tissue or superficial coagulation and contraction dependent on the chosen power setting.

SCANNING HANDPIECES:

The Lumenis UltraPulse® has two scanning devices, the UltraScan C-P-G (Computer-Pattern-Generator) and the microscanner handpiece. The UltraScan is the scanning device for a mode called "ActiveFX®". The ActiveFX® has a collimated spot size of 1.3mm with various choices for pattern shapes and sizes, allowing for adaptation to different clinical situations. The depth is related to the chosen fluence and extends to around 300 microns (0.3mm), allowing for superficial resurfacing of fine lines and texture. The density ranges from fractional (density 1-3) to full field with overlapping (density 4-9). The handpiece has a sophisticated method of delivering the individual spots in a non-sequential random pattern manner "coolscan technology" thus allowing for the tissue to cool in between and avoiding any "hot spots". The microscanner device has both the "DeepFX®" and "SCAAR FX™" (Synergistic Coagulation and Ablation for Advanced Resurfacing) modes. The DeepFX® has a range of fluence up to 50mj and a spot size of 0.12mm, hence with such a great power of the laser (240 W) coupled with a very short pulse width (less than 0.8ms) this will allow for a deep penetration of up to 1.5mm. The software allows for a double pulse mode if necessary on the same spot. Different shapes and sizes are available with a range of densities allowing for precise spot or larger area coverage. The combination of the two treatment modalities with both the ActiveFX® and DeepFX® is referred to as "TotalFX®". It is this unique feature of the Lumenis UltraPulse® machine to give the opportunity for both superficial ablation together with deep fractional treatment with variable densities that surpasses it from other currently available CO2 machines. The SCAAR FX™ mode allows for the greatest depth penetration of any CO2 laser of up to 4mm, enabling us for the first time to treat hypertrophic or deep burn scars. The density pattern ranges from 1 to 5% with a single pulse mode only. The energy starts from 60mj to a maximum of 150mj; the highest energy in any CO2 laser with a small spot size and very short pulse duration. In both handpieces the ratio of ablation to coagulation is consistent (increases with higher energy) allowing for greater safety use.

COMBINATION THERAPY:

The UltraPulse® CO2 has been combined with other treatment modalities for maximum clinical efficacy. Examples include the use of pulsed dye laser for erythematous scars prior to the use of CO2. Anti-ageing treatments such as botulinum toxin and filler injections have also been used post CO2. More recently, the UltraPulse® CO2 has been used as a mode of drug delivery, a novel approach to delivering certain drugs or molecules through deep ablated channels. This has been particularly beneficial in the treatment of hypertrophic scars.

CONCLUSION:

The Lumenis UltraPulse® is the most versatile and powerful CO2 machine in the world. The sophisticated pulse profile coupled with very short pulse duration and a high peak power allows for the greatest tissue depth penetration of any CO2 machine with a favourable ablation to coagulation ratio. The various handpieces available allow for a versatility of treatments ranging from superficial to deep resurfacing in both fractional and conventional modes.

Lumenis®