UHMWPE: EFFECT OF GAMMA RADIATION ON THE CROSS LINKING AND OXIDATIVE BEHAVIOUR STUDIED WITH THE CHEMILUMINESCENCE APPROACH.

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INTRODUCTION: Ultra high molecular weight polyethylene (UHMWPE) is a subset of the thermoplastic polyethylene. It has extremely long chains, with molecular weight usually between 2 and 6 million. The longer chain serves to transfer load more effectively to the polymer backbone by strengthening intermolecular interactions. This results in a very tough material, with the highest impact strength of any thermoplastic presently made. It is highly resistant to corrosive chemicals, with exception of oxidizers. It has extremely low moisture absorption, has a very low coefficient of friction, is self-lubricating, and is highly resistant to abrasion. It is odorless, tasteless, and nontoxic.

Due to these properties, UHMWPE is used over 40 years as a successful biomaterial in hip, knee, and most recently for spine implants. Throughout its history, there were unsuccessful attempts to modify UHMWPE to improve its clinical performance; one attempt is the cross linking by gamma or electron beam radiation since the late 1990s.

The high energy radiation treatment leads UHMWPE susceptible to oxidative decay, due to the formation and accumulation of radical species in the polymer matrix.

METHODS: The susceptibility of UHMWPE against cross linking and oxidation was studied with the Chemiluminescence (CL) method. Degradation of hydrocarbon polymers involves a radical chain reaction, which propagates in the presence of oxygen. The CL emission mechanism arises from the phosphorescent relaxation of a triplet carbonyl species, formed in a bimolecular termination reaction by the Russell mechanism or by direct hydroperoxide decomposition. The CL-data were measured with a 1^{10} basic configuration from ACL Instruments. All samples were characterized at 37°C; after initial 24h in nitrogen (4N), the atmosphere was switched to synthetic air for additional 24h.

UHMWPE discs (dia 15mm) in different variations were supplied by Dr. Lukas Eschbach, Robert Mathis Foundation RMS (Betlach CH): not irradiated (0Gy) and irradiated 75...111kGy, each of them unstabilized and stabilized (Vitamin E).

RESULTS: The CL-data were visualized (Fig. 1) and the Total Luminescence Intensity (TLI = Integral of the CL-emission) for the nitrogen and air segment were calculated (Tab. 1).

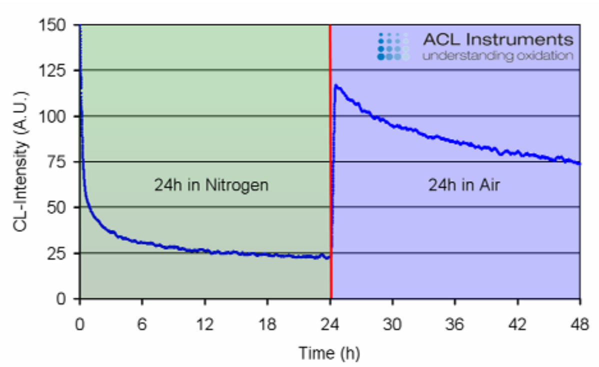

Fig. 1: CL-experiment of gamma radiation treated, Vitamin E stabilized UHMWPE: CL-emission due to cross linking in nitrogen (green part) and due to oxidation in synthetic air (blue part). The red line represents the time of switching the atmosphere from nitrogen to synthetic air).

Gamma	AO	TLI (counts)		Factor
		24h (N_2)	24h (Air)	Air vs. N_2
75..111kGy	Vit. E	209'049	641'938	3.07
0Gy	none	17'104	23'238	1.29
0Gy	Vit. E	11'314	12'656	1.12
75..111kGy	none	123'137	227'706	1.89

Table 1. Total Luminescence Intensity TLI depending on the gamma radiation treatment and the AO-stabilization.

DISCUSSION & CONCLUSIONS: The CL emission study indicates the following behaviour: Due to the gamma radiation treatment, the UHMWPE samples crosslink. This effect clearly appears in inert gas atmosphere at low temperature where the TLI is more than 10 times higher on the irradiated samples than on not irradiated samples. In the oxidising environment, the TLI values of gamma irradiated samples increase dramatically (factor higher than 25). The stabilisation of UHMWPE with Vitamin E increases the susceptibility to cross linking but also to the oxidation. On the other hand, the not irradiated, unstabilized samples are less stable against oxidation compared to the stabilized samples.