

# Preliminary Study on Erosion of Polymer Coatings of Duodenoscopes

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*Medical devices' field is developing very fast and the polymers represent next to biocompatible alloys a priority to the research field. The duodenoscopes are intensely used for diagnosis and treatment of various pancreatic and biliary diseases, being in contact with all liquids from saliva, gastric juices and bile liquids. Next to the aggressive environment physical erosion occurs. Using the optical microscopy the superficial polymer coating was analyzed. The deterioration of the coating is increasing the risk of infections and biofilms.*

*Keywords: erosion, optical microscopy, medical polymer, infection risks, biofilm*

Duodenoscopes are medical devices used to diagnose, treat or palliate a multitude of pathological conditions of the bile ducts and pancreas. They are different from standard digestive endoscopes by their complex design involving the presence of an elevator channel located at the tip of the endoscope that permits manipulation of different accessories primary used in endoscopic retrograde cholangiopancreatography (ERCP) [1]. Duodenoscopes are multiple use devices requiring cleaning, high-level disinfection (HLD) or sterilization and subsequent drying dependent on the recommendations of the manufacturer [2].

First ERCP procedures are mentioned as far as 1968 [3] and since then it has become an indispensable procedure for almost all interventional endoscopists. To date, more than 500000 ERCP procedures are performed each year in the United States providing a less invasive treatment for pancreatic and biliary diseases [4]. In the last decades the role of ERCP has evolved from a mainly diagnostic one to a highly therapeutic one [3], allowing endoscopists to perform endoscopic sphincterotomy, insert biliary or pancreatic stents, remove bile duct stones, perform dilation of stenoses or to take brush cytology samples.

Nevertheless, ERCP is well known for its risks, complications and adverse effects, therefore being considered the most difficult to perform endoscopic procedure. All these potentially negative aspects can be classified as pre-procedural, intra-procedural or post-procedural conditions. Early recognition and prompt management of adverse effects and complication is a key factor to the optimal management of ERCP-related mortality and morbidity.

The last several years have been marked by a deep change in the interest for ERCP-related adverse effects and complications. If in the former years post-ERCP pancreatitis, followed by bleeding or perforation were well studied complications [5,6], recently ERCP-related infections became a dominant point of interest for a great part of the medical community. The problems related to duodenoscope-associated infections and their human-to-human transmission despite thorough reprocessing

methods have stated new challenges for cleaning and disinfection of such medical devices worldwide [7].

## *Duodenoscope-related infections*

First duodenoscope-related infection was presented around almost 30 years ago [8]; historically, endoscope related infections were characterized by the constant thread of reprocessing errors or lack of adherence to the reprocessing protocols indicated by the producers [9, 10]. Transmission of such infections despite producer recommended reprocessing protocols was recognized only recently, the main cause being considered the difficult-to-clean duodenoscope devices which are able to select, harbor and move multidrug-resistant bacteria. Most importantly, as current studies state, such infections occur despite recognizable breaches of standard reprocessing protocols [11, 12].

Over the last years, an outbreak of duodenoscope related patient-to-patient transmitted infections have been reported [1] in both original research articles and the media. This became an even hotter topic as soon as the occurrence of duodenoscope-transmitted multidrug-resistant bacteria was demonstrated. As soon as some of the first subsequent studies were able to prove the existence of multiple carbapenem-resistant Enterobacteriaceae infections after ERCP in a suburban Chicago cluster [12, 13], followed by the discovery in 2015 of multiple such clusters along the United States, energetic administrative, political industrial and social reaction has been seen. The US Food and Drug Administration (FDA) after issuing two safety alerts regarding duodenoscope-related infections [14-16], reacted with an FDA expert panel that would provide new recommendations and guidelines that would assure a higher degree of safety for clinical care [17]. Subsequent political concern was risen and therefore as recently as 2016 the US Senate released an investigative report that led to FDA and industry recall of certain duodenoscopes from the market [18, 19].

Unfortunately, as this very hot problem is also a recent one, the literature of the field very eloquently stated that all this infection-control issued around duodenoscopes have

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raised more questions than answers, many of these being tributary to the laws and regulations surrounding medical devices [20]. Rapidly, the discovery of duodenoscope-related multidrug-resistant bacteria clusters in the US led to similar studies worldwide, and several systematic studies have been able to prove in the last years the existence of such clusters around the world [20]. Over 250 patients for over 23 hospitals worldwide were showed to have been affected by such infections recently [7]. Subsequently duodenoscopes are more and more seen as a vector of infection among medical devices [20]. Moreover, reliability and general public view on ERCP procedures has had much to suffer throughout the last years and not even to date has there been found any responsible party for such worrisome situation.

Traditionally, since 1968, medical devices have been categorized in three general classes tributary to the Spaulding classification [21]. Such classification is based upon the specific risk for infection of each medical device and has been used in order to determine appropriate type of disinfection and/or sterilization to be used. Medical devices are classified as:

1. Critical devices – medical devices entering sterile tissue or blood vessels. These devices should always be sterile;

2. Semicritical devices – medical devices that come in contact with mucous membranes and/or non-intact skin. These devices require high-level disinfection (HLD). Digestive endoscopes and duodenoscopes have been considered semicritical devices;

3. Noncritical devices – medical devices that come in contact only with intact skin. These devices are considered safe if at least cleaned with usual surface disinfectants.

Even if throughout the time since their worldwide use digestive endoscopes have been considered semicritical devices requiring various types of HLD, after discovery of the aforementioned duodenoscope-related infections, questions have been raised upon the necessity of reclassification of duodenoscopes or related devices. Firstly, it has been clearly shown that even if endoscopes are semicritical devices, associated and adjunct devices like biopsy forceps and sphincterotomes are critical devices that should be sterilized after each procedure [22]. Therefore, a problem not resolved by the Spaulding classification is that of semicritical devices in need of being used in conjunction with critical devices [23, 24]. Whether or not HDL is still a gold-standard for these devices is debatable.

### Reprocessing duodenoscopes

As the literature of the field has always stated, the efficacy of world widely used HLD practices was time-validated and time-tested within a very narrow safety margin for eradication of endoscope contaminating microorganisms [25]. While sterilization can be defined as the process leading to complete absence of any type of contaminating microorganism, as stated by the US FDA HDL is a reprocessing method aiming at inactivating a large amount of microorganisms (such as bacteria, viruses or fungi) to a extent of  $10^6$  to  $10^9$  reduction of the endoscope bioburden [2, 5, 24]. When reported to each reprocessing procedure,  $10^3$  organisms should be lost during pre-cleaning, and up to  $10^6$  organisms are expected to be reduced during manual washing. Furthermore another  $10^6$  to  $10^9$  bioburden should be reduced during HLD secondary to the exposure to liquid chemical germicides [5]. Such germicides, in order to be cleared as HLD chemical agents must show standardized proof of antimicrobial activity against

vegetative bacteria, viruses, fungi, including highly resistant bacterial endospores [7]. Chemical substances often used as HLD agents are mainly aldehydes (e.g. glutaraldehyde) and oxidizing agents (e.g. per-acetic acid).

Endoscope reprocessing means some conjunct methods applied in order to minimize the bioburden of various endoscopes after each use. First, each device should be cleaned manually after each use at bedside for residual soil. Afterwards the endoscope is run through several tests that would detect leakages or damages of the device after usage. Subsequently each endoscope is chemically cleaned after manual cleaning, this second cleaning process being tributary to chemical detergents. Only afterwards is the device ready for HDL or sterilization. Both HDL and sterilization are achieved by immersion of the medical device in the liquid chemical agent or by gas exposure (e.g. is case of ethylene-oxide sterilization). Finally the device is ready for another usage or for storage. Such reprocessing cycle alongside with its weak points and threats is shown in figure 1, as it is very eloquently illustrated by Humphries et al in a recent paper on duodenoscope reprocessing [7].



Fig. 1. Reprocessing cycle of duodenoscopes. Breaches and threats for gold standard reprocessing protocols are shown with exterior arrows, as illustrated by Humphries et al, 2015 [7]

Even if producer-issued protocols for duodenoscopes have always been drafted and therefore granted by day to day practice, in the most recent context of duodenoscope related infection bursts most producers reviewed the standard protocols making them harder and harder to comply, monitor, validate or even follow-up. High rates of failure in following-up the producer protocols are reported in the literature, from modest values of 28% failure [25], to alarming success rates reported of just 1.4% [26]. Compliance to thorough reprocessing is therefore considered inconsistent and unreliable [1] and the human factor is seen as the one most prone to error [26]. Nevertheless, unfortunately, there are still no consistent, intensive and validated methods for monitoring HLD and duodenoscope reprocessing [27].

Another threat for duodenoscope reprocessing is considered to be their complex technical structure. As stated by the vast majority of recent studies, HLD in duodenoscopes needs to be achieved not only for the outer surface of the medical device but also to the inner working channels and wire channels, especially in what the older

models of duodenoscopes with no sealed elevator channel are concerned. Moreover, the recess from under the elevator is usually concealed and isolated during the pre-HLD steps in this way formation of resistant microbial biofilms seem to occur [1]. Some producers are now redesigning these features of duodenoscopes. Despite these technical design changes, ERCP-related infection outbreaks were reported in connection also to these new duodenoscopes [28, 29].

This is the reason why more and more studies claim that there should be something more related to duodenoscopes than their complex structure that makes them vectors for multidrug resistant infections. Any unanticipated damage in the proximity of the duodenoscope tip may lead to persistent bacterial colonization [1] and resistant bacteria selection. This hypothesis is promoted also by the fact that the outer surface of duodenoscopes is an inert surface that when exposed to repeated and invasive wear may alter and become more susceptible to contamination with difficult to clean bioburden [30]. Such hypothesis is followed also by our study that aims to demonstrate in the following experimental part the alterations of the outer inert surface of duodenoscopes that appear in connection to normal usage of the medical devices.

The current study is a preliminary evaluation of the polymer coatings of duodenoscopes, which have multiple functions. The duodenoscope is in contact with all liquids from saliva, gastric juices and gall liquids, next to erosion. Direct imaging was used to identify the superficial erosion with the help of an optical microscope

## Experimental part

### Materials and methods

Two standard duodenoscopes were involved in the study, one new – as reference and one after appreciatively 1 year of normal use.

The optical micrographs were obtained using a Zeiss Imager A1m microscope, using dark field and bright field filters, at magnifications between 50X and 200X, which is

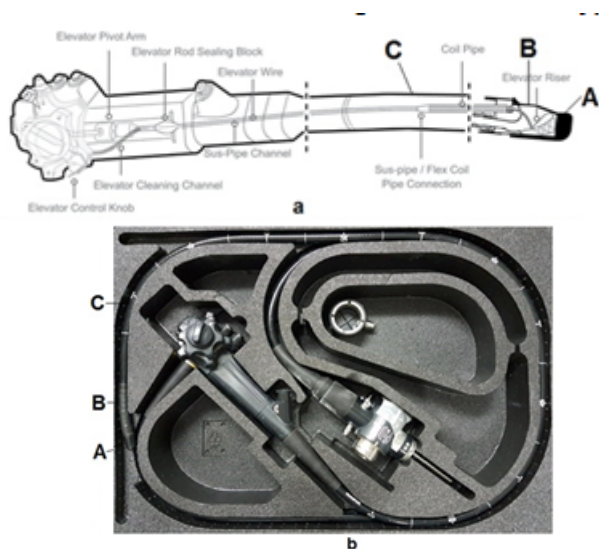


Fig. 2. The duodenoscope: a - constructive scheme [31] and b - image of a duodenoscope with the analyzed areas A, B and C

Operation	Time	Solution composition	pH
Cleaning	15 minutes	decimethylamonium propionate, polyhexanide, surfactants, enzyme complex, 0,5% dilution, in room temperature water	~ 7
Disinfection	15 minutes	decimethylamonium propionate, polyhexanide, surfactants, enzyme complex, 0,5% dilution, in room temperature water	~ 7
HLD	15 minutes	stabilized glutaraldehyde 20%	~ 6

**Table 1**  
THE REPROCESSING  
PROTOCOL

attached to a camera and specialized software AXIOCAM. Further studies will involve scanning electron microscopy.

Three areas were selected next to the interface between two of them:

A – the top end area which is the most subjected to friction;

B – the intermediate area which requires the most elasticity;

C – normal polymeric coating;

A-B – the interface area between A and B where a polymeric binder is used.

Reprocessing protocol of duodenoscope (model acquired in 2014, 150 ERCPs) is presented in table 1.

After these treatments the duodenoscopes are dried and than stored or used.

## Results and discussions

Using the optical microscopy the superficial layer can be clearly observed in figure 3.

The areas selected for the analysis are made from different composition and texture, having different functions and due to this were analyzed in both dark field, which shows real color of materials, and also bright field.

The polymer coating of the duodenoscopes presents multiple structures and composition, from here the different deterioration of it.

The experimental part of the study clearly showed that even normal day to day usage of duodenoscopes may lead to surface damages, probably making them prone to harboring multiresistent extremely adherent bioburden, capable to defy HLD [32].

Such biofilm is seen as difficult to eradicate as harbored bacteria are 10-1000 times more resistant to antibiotics than planktonic cells [33]. It has been reported that concentrations of antibiotics required to achieve bactericidal activity against such adherent organisms can be three to four orders of magnitude higher than for planktonic bacteria, depending on the species-drug combination [34]. Furthermore, when assessed by various molecular-biological and microscopic techniques, the bacteria within a biofilm appear as physiologically heterogeneous, this being highly significant for resistance to antibiotics [35].

Consequently, as to what the cause of such bioburden is concerned, according to a recent review article, a consistent number of studies concluded that many of the duodenoscope-transmitted infections occurred independently on any breach in reprocessing protocols or device quality [36]. Moreover, similar endoscope transmitted infections have been demonstrated also in gastroscopes and colonoscopes [37, 38], therefore also the outer surface of the medical device could be incriminated, despite the complex technical structure of the duodenoscope. Cross-contamination of endoscopes during reprocessing could also play an important role [39]. Findings of a recent study show that such endoscope related infections occur independently on the producer of the medical device, on the HLD protocol used or on the endoscope model studied [40]. Such hypotheses are sustained also by a systematic review of research papers



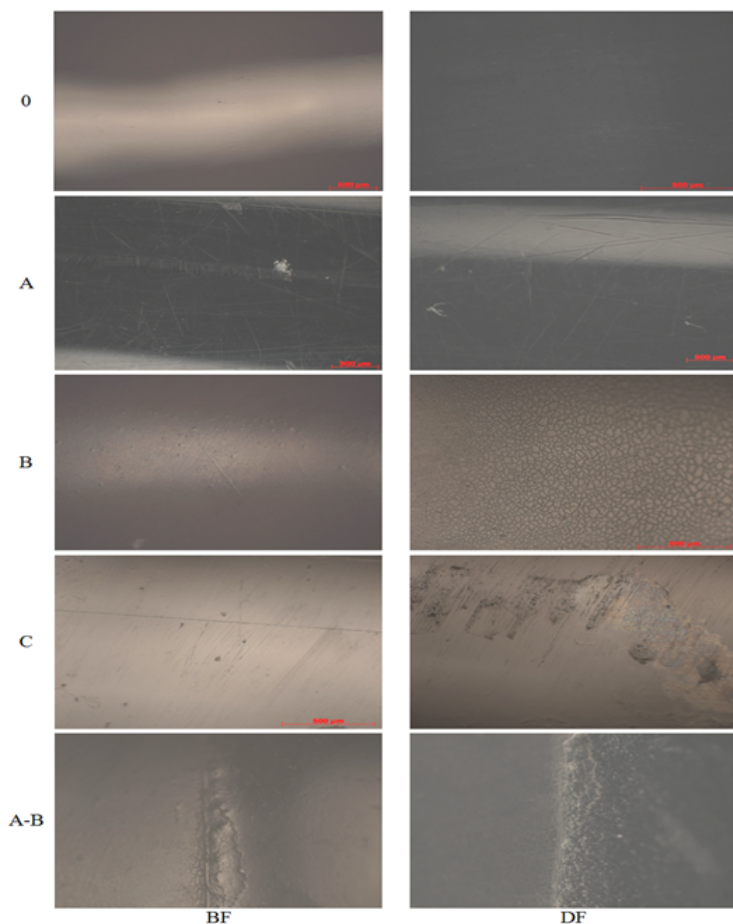


Fig. 3. The optical micrographs on the analyzed areas using bright field (BF) and dark field (DF) filters at magnification of 50 and 100X

on duodenoscope-transmitted infections, which states that in the majority of studies involved a specific source related to the duodenoscope was not discovered [36]. These results may once more generate the idea that the potential multidrug resistant biofilm is a diffuse bioburden on endoscopes. Such bioburden load may be promoted by surface alterations of medical devices which even if associated with normal use may promote aggregation and adhesion of microorganisms [41].

As it is normal, the unused coating (the new one) presents no scratch or deterioration on the surface, compared to the used ones in various locations, as the one selected by us and marked with A, B and C. A zone is the area with the most friction, being at top end of the device. The second area, B, is the one with the most elasticity required - presenting a texture with superficial microcracks. The C area presents longitudinal scratches due to the erosion on insertion and removal of the device from the tract. The interface between A and B is made of a binder polymer with small superficial porosity, which can be susceptible to biofilm formation.

### Conclusions

Duodenoscope-related infections may be seen as a major health issue world-wide. Conjunct effort is made on sorting out its causes and on finding solutions in order to assure the best possible standard of care and outcomes for patients undergoing ERCP. Thorough assessment through experimental studies of duodenoscope structure may generate new ideas on potential weak points related to duodenoscope biofilms.

Regular usage of duodenoscopes lead to surface damages. The properties of the coatings are very important, requiring high elasticity and microhardness, next to antimicrobial activity. The occurred degradation by erosion or the chemical interactions influence the surface susceptibility

to infection. Further studies will evaluate the possibility to enhance these.

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