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Diamond - Like Carbon Coating is a New Strategy to Improve the Surface Properties of Biliary Stents.

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ABSTRACT

Our performed research shows possibilities of application of plastic diamond-like carbon (DLC) coated biliary stents at difficult choledocholithiasis. In the tests in vitro, while stents incubation within 90 days at 36.6° temperature, in the bile got from patients with choledocholithiasis it was detected that DCL covering 6.5 times decreases calcium salts build-up at the stent surface (total weight fraction of the element is 1.78%, total element atomic fraction is 0.58%, in the control group – 11.54% and 10.51% respectively, $p < 0.05$). Average term of DLC stents operation in patients with choledocholithiasis made 145.5 ± 12.4 days, in the control group – 105.3 ± 12.4 days ($p < 0.05$).

Keywords: bile duct stones, stent, diamond-like carbon.

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INTRODUCTION

Works published in the recent time have showed that trans-papillary stenting of bile ducts in elderly and later aged patients with serious underlying diseases not only enabled stable elimination of bile hypertension, but it frequently became the final modality for treatment of difficult choledocholithiasis [1, 2]. Main failures of the existing techniques for biliary stenting are necessity to replace stent due to quick obturation of the internal lumen. Today, one is widely discussing the problem of effectiveness of bile outflow through self-expandable metallic stent of different construction materials and configuration; at this, one does not almost highlights the technologies for life extension of the most widely spread of plastic stents [3-8].

TECHNIQUE

In the tests in vitro, stents experimental batches have been incubated within 90 days at temperature 36.6° in bile got from the patients with choledocholithiasis. For evaluation of clinical efficacy of the offered stents, we made a group of 23 patients with choledocholithiasis at unsuccessful attempts of endoscopic removal of stones and existence of counter-indications to traditional operations because of elderly age and serious somatic pathology. The main group (n-12) comprised patients with stenting by plastic DLC coating stents; in the control group (n-11), stenting was performed with standard plastic stents without coating.

MAIN PART

While incubation of experimental batches of DLC stents in vitro within 90 days at temperature 36.6° in bile got from the patients with choledocholithiasis, it was determined authentically less amount of solid deposits and scale incrustation by bile salts at their surface compared to the stents without coating (Fig. 1).

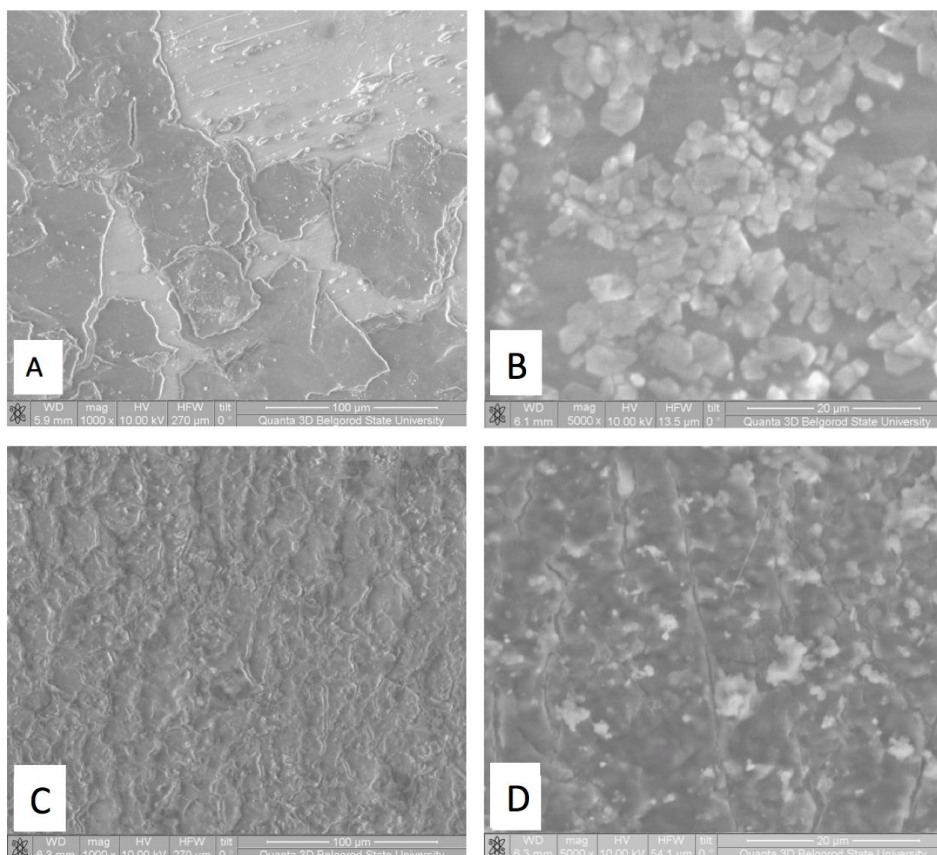


Figure 1: Scanning electron microscopy of biliary stents under study (A. – stent without carbon coating, zooming in x 100 (there are multiple solid deposits in view of layers), B. – stent without coating, zooming in x 5000 (multiple scale incrustation by bile salts), C. – DLC coating stent, zooming in x 1000 (on the surface, one sees distinct "contraction" of nano-surface, there are unique white bile crystals), D. – DLC coating stent, zooming in x5000 (one detects imperceptible cracking of carbon nano-surface and unique scale incrustation by bile salts).

Results of X-ray energy-dispersive microanalysis of stents under study in order to determine the ultimate composition are given in the Table 1.

Table 1: Ultimate composition of surface of plastic stents under study.

| Element | Wt. % | | At. % | |
|---------|----------------|------------------|----------------|------------------|
| | Control group | Main group (DLC) | Control group | Main group (DLC) |
| C | 57.8 ± 0.3985 | 73.35 ± 0.4199 | 68.44 ± 1.0054 | 79.72 ± 1.0052 |
| O | 24.43 ± 0.0385 | 23.40 ± 0.0385 | 20.55 ± 0.9914 | 19.10 ± 0.9911 |
| P | 0.24 ± 0.0020 | 0.32 ± 0.0027 | 0.11 ± 0.9264 | 0.13 ± 0.9262 |
| S | 0.94 ± 0.0086 | 2.15 ± 0.0107 | 0.39 ± 0.9514 | 0.47 ± 0.9512 |
| Ca | 10.54 ± 0.0151 | 1.78 ± 0.0175* | 12.51 ± 0.9224 | 0.58 ± 0.9221* |

Note: Wt, % - element total weight fraction, At, % - element atomic fraction,
 * - authenticity of difference of average values in the groups under study (p<0.05).

Average term of stents operation in main group patients with choledocholithiasis made 145.5±12.4 days (maximum – 386), in the control group – 105.3±12.4 and 127 days respectively (p<0.05). At this, the main reason of stents dysfunction, and, consequently, indication to their replace, was obturation on the internal lumen by bile salts (Fig. 2).

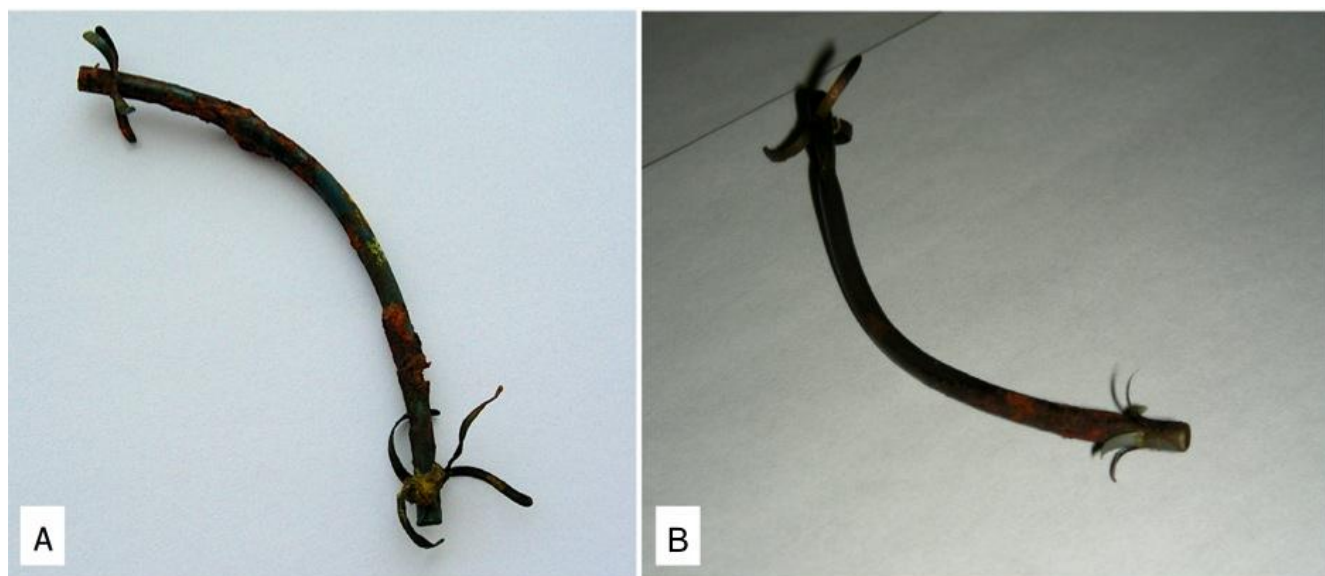


Figure 2: Stents removed from bile ducts in patients with choledocholithiasis (A – stent without coating: massive incrustation by bile salts, lumen occlusion with beginning of clinical dysfunction at 87th day; B – stent with DLC coating, bile salts incrustation is not detected, lumen occlusion with beginning of dysfunction at 192nd day).

AFTERWARDS

Body response to implant is mainly determined by its surface behavior: chemical composition, structure and morphology. In this regard, of special interest are means for regulating biological properties of medical goods intended for change physical and chemical properties of the surface [9]. From this point of view, diamond-like carbon coating is a very interesting fact [10]. In the tests in vitro, it was determined authentically less amount of solid deposits and scale incrustation by bile salts at the DLC coating stents surface compared to the stents without coating. The prove for this fact, there is an X-ray elementary microanalysis of stents surface under study that has determined authentically less amount of calcium on the surface of DLC coating stents. One knows two kinds of biliary calculus: cholesterol and pigmental. Cholesterol bile stones consist mainly of

cholesterol, mucin, bilirubinate, phosphate, carbonate, and calcium palmitate. Pigmental stones consist of calcium bilirubinate; they comprise carbonate and calcium phosphate, as well as great amount of mucin glycoprotein. At this, calcium salts have a leading part in stone formation pathogenesis [11]. It let us draw a conclusion that DLC coating decreases calcium salts build-up at the stent surface by prolonging its lifetime.

CONCLUSIONS

Our investigation showed the possibility of application of plastic DLC coated biliary stents for long-term draining of bile ducts at difficult choledocholithiasis complicated by obstructive jaundice.

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