Basalt fiber manufacturing technology and the possibility of its use in dentistry

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Abstract. The article touches upon the technology of basalt fiber manufacturing and prospects of its use in dental practice. Two kinds of construction using basalt fiber have been proposed. The first one is a splinting construction for mobile teeth and the second one is the reinforced base for removable plate-denture. The work presents the results of the investigation of physical and mechanical properties of the constructions based on basalt fiber. It also describes the aspects of biomechanical modeling of such constructions in the ANSYS software package. The results of the investigation have proved that applying constructions using basalt fiber is highly promising for prosthetic dentistry practice.

1. Introduction

Basalt is magmatic rocks, highly resistant according to their chemical and mineral composition. Its geological reserves are practically unlimited in the world and range from 25 to 38% of the total area occupied by all magmatic rocks. The reserves of basalt are considered to be inexhaustible as it has been estimated that they are refilled at the rate of 1 million m³ per year due to volcanic activity [1]. Basalt is used as a raw material for the production of road metal, cast stone material, powdering material and basalt fiber, which, in turn, is used in building, power industry, mechanical engineering and aircraft as well as chemical, nuclear and other industries. Such a wide use of basalt and basalt fiber can be explained by its low cost and good physical and mechanical properties, resistance to high temperatures, acids and alkali. Taking into account the relative inactivity of basalt fiber, it could be used in medicine. However, the analysis of scientific literature has shown no evidence of its use in medical science. In dental practice we can suggest two possibilities of basalt fiber use: periodontal splinting and reinforcing removable laminar dentures.

2. Technology of basalt fiber manufacturing

The basalt fiber production process begins with fragmentation of coarse basalt aggregate into finer grains sized 5-12 mm. Dimensions of the grains can be controlled using different methods [2, 3]. After selecting metallic inclusions by magnetic separation, basalt raw material in the form of riprap stones or chips is griddled, washed and dried under the conditions of natural airing or in a special drier. After that, the basalt chips are put in a reservoir installed above a melting furnace. Melting furnaces may be
electrical, gas or equipped with fuel oil burners. In a melting furnace, basalt raw material is liquefied at the temperature of \((1500 \pm 50)\ °C\) and, when homogeneous, enters a feeder to be then formed into complex continuous basalt fibers. The melted material from a furnace gravitates into the feeder with platinum drain valves located at the bottom. Through those, the melted material flows to a platinum-rhodium electric-traced stream feeder assembly, where a strand of elementary continuous fibers is formed by extension and reeled to a pulling mechanism. It applies an oil agent and after that all fibers are gathered together into one complex thread or fiber. A complex fiber passes through a special thread-distributing apparatus and is rolled on a removable bobbin, which is in due time removed and replaced by a new one. A winding apparatus forms continuous basalt fiber consisting of 314 elementary basalt threads. Full bobbins are held under normal conditions for one day to be then taken for rewinding to receive a roving with the necessary number of compositions.

3. Basalt fiber splint construction
Splinting is constriction of teeth with a thin thread to decrease and prevent further increase in their mobility. This method is one of the ways to increase the effectiveness of periodontal disease treatment. According to the data of the World Health Organization, the incidence of periodontal diseases amounts to 80-100% [4]. Splinting is necessary for 40-50% of such patients. There are many materials for splinting but all of them have some flaws such as: separation of fibers while cutting and modeling, poor adaptation to teeth, difficulty of use while working [5, 6]. We suggest using a basalt fiber splint, which has no such disadvantages [7]. To prove the rationality of such a splint in dental practice, we carried out a biomechanical modeling of splint construction made of basalt fiber. Using the ANSYS software package we counted the intensity of resultant Von Mises stress in the lower jaw, teeth and basalt fiber. The mechanical properties of teeth, lower jaw bone tissue and basalt fiber were taken from the literature and are presented in Table 1. According to the results of the biomechanical modeling, the maximal intensity of stress occurring in case of basalt fiber splinting reaches \(6.763 \times 10^7\ Pa\) (Fig. 1) which is well within the strength limit. That is why we can recommend basalt fiber as a periodontal splinting material.

![Figure 1. Intensity of resultant Von Mises stress in the lower jaw, teeth and basalt fiber](image-url)
Table 1. Mechanical properties of teeth, lower jaw bone tissue and basalt

| № | Parameter                              | Teeth       | Lower jaw bone tissue | Basalt         |
|---|----------------------------------------|-------------|-----------------------|-----------------|
| 1 | Young modulus \( E \), GPa            | 1.8 \( \cdot 10^4 \) | 10                     | 87.1±2.3        |
| 2 | Poisson ratio \( \nu \)               | 0.3         | 0.3                   | 0.4             |
| 3 | Limit of strength \( \sigma_{st} \), MPa | 11.5        | 100                   | 2245.3±126.8    |

4. Reinforcing removable laminar dentures

The need for orthopedic treatment with removable dentures is very high and amounts to 33-58% according to V.N. Kopeikin and co-authors (1994). Due to a marked demographic shift towards population ageing observed in recent years, it has become more urgent reaching 65+% [8]. Nowadays 90% of dentures are made of acrylic plastics because of their low price and easy production. However, these plastics have some disadvantages, one of which is considered to be their insufficient mechanical resistance. This is proved by prosthetic basis fractures ranging from 3 to 15% of breakages during the 1st year of use or 19% during the whole 3-year period of dispensary observation [9]. In such a case prosthetic basis fractures cause severe discomfort and additional material expenditures to a patient and bad reputation to a doctor. The existing method of reinforcing with gold-foil is not only expensive but also does not allow doctors to avoid primary fractures. We suggest using the method of acrylic plastic reinforcing with basalt fiber at the stage of removable laminar denture production. This will make it possible to avoid denture fractures during the entire period of their use. To prove the rationality of using this method, we conducted physical-mechanical investigations according to all-Union State Standard 51889-2002 “Polymeric materials for tooth denture basis. Technical demands. Test methods”. 8 samples of acrylic plastic and 8 more of acrylic plastic reinforced with basalt fiber were made for the investigation. Using the Instron 5965 testing machine (Fig. 2), we investigated the dependence of strain-movement (Fig. 3, 4) with the subsequent calculation of the strength limit and elasticity modulus. As a result of the investigation, the strength limit and elasticity modulus of non-reinforced samples amounted to 67.1±0.6 GPa and 2010±9.3 MPa. In the reinforced ones, these indices were higher: 71.9±0.7 GPa and 2021±8.9 MPa respectively (Fig. 5). That is why we have made a conclusion that the use of basalt fiber to reinforce removable dentures improves their strength characteristics and can prevent their fractures.

Figure 2. Instron 5965 testing the three-point bending: sample (1), loading plunger (2), supporting cylinders (3).
Figure 3. Dependences of strain-movement obtained while testing the three-point bending of acrylic plastic samples.

Figure 4. Dependences of strain-movement obtained while testing the three-point bending of acrylic plastic samples reinforced with basalt fiber.

Figure 5. Comparison of the strength limit and elasticity modulus of the bases of acrylic plastic (A) and acrylic plastic reinforced with basalt fiber (B).

5. Conclusion
Having analyzed the data obtained, we have come to the conclusion that basalt fiber is a promising material for dental practice. A splint made of basalt fiber both meets all the necessary requirements and has a high strength reserve. Moreover, a basalt fiber splint is much cheaper than its competitors: splints made of polyethylene and glass fiber. And finally, bases reinforced with basalt fiber have high physical and mechanical characteristics, make it possible to avoid denture fractures and prolong the period of its use by a patient.

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