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Transdental Fixation Using Monocrystalline Aluminum Oxide Ceramic Pins

Summary

The monocrystalline pins (1) were developed on the basis of experience gained with polycrystalline aluminum oxide ceramic pins. Compared to the polycrystalline structure the monocrystalline pins offer a higher bending strength. In addition to a polished surface finish it was possible to achieve a microroughness, which is similar to the surface roughness of polycrystalline pins, due to a new procedure of thermal surface treatment. These new ceramic pins allow for realizing longer transapical fixations and for manufacturing even finer pins, which still offer an adequate fracture strength. In a biological environment the surface reactions are expected to be comparable to those of polycrystalline pins.

1. Introduction and Tasks

Transdental fixation is applied for the conservation of teeth the turning point of which has been shifted into coronal direction as a result of a reduction in height of the alveolar crest or of bone-destructing apical changes (osteitis, cyst, etc.). This turning point can be shifted into apical direction and a better prognosis be achieved by extending these teeth artificially. The principles of transdental fixation are already known and were described in detail by Wirz [11].

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Al_2O_3-ceramics are biocompatible [2, 5, 9]. Kirschner introduced the method of auto-alloplastic re-implantation, which also uses oxide ceramic pins; the histologic evidence confirms the results of the investigations mentioned before [7]. Therefore, it was only reasonable to use this material for transdental fixation, all the more so since it is frequently applied for endosseous implantation [3].

Today the percentage of aluminum oxide contained in high-grade aluminum oxide ceramics ranges at 99,7 %, due to which even polycrystalline pins achieve almost the mechanical properties of metallic materials [1, 4]. The monocrystalline pin bodies are drawn from a melt at a temperature of 2.500 °C and are then machined with diamond tools in order to obtain the shapes and dimensions required. During this process a multitude of microcracks and other defects are generated on the surface, reducing the mechanical strength to a considerable extent. In order to eliminate these strength-reducing defects and to increase the mechanical strength significantly, further surface treatment is to be effected by means of chemical or thermal polishing. Thus, it is generally possible to achieve very smooth surfaces, which, however, do not promote bone adaptation. For manufacturing pin bodies of polycrystalline aluminum oxide, on the other hand, high pressures are used to compress the starting material, which is then sintered at temperatures slightly below the melting point [4]. Although this procedure provides for only 50 % of the mechanical strength offered by monocrystalline material, which may also be described as synthetic sapphire, it allows for achieving a micro-roughness of the suface, which promotes bone adaptation [7, 9].

The following requirements had to be met:

1. The bending strength of the ceramic pins had to be increased, particularly in the case of pins destined to extend the teeth far beyond the apex;
2. A favourable surface structure had to be achieved.

2. Material and Method

There were four different variations of aluminum oxide ceramic pins available: polycrystalline pins and monocrystalline pins with ground, polished and structured surfaces. The axial compressive strength of the pins was not tested since it is as high as 5000 MPa in the case of polycrystalline pins and therefore is not expected to cause any problems. Since the bending strength of finer pins is critical, it was tested on all four pin variations mentioned before. In addition, the micro-roughness was determined. The monocrystalline aluminum oxide ceramic pins with structured surface, which proved to be the most favourable type of pins in this test, were used for clinical implantation in 20 cases. For this purpose the root canal of the tooth was prepared as usual and an apicectomy carried out. Further preparatory treatment for adapting the root canal to the pin diameter of 2 mm, 2,5 mm or 3 mm was effected with shaft drills with internal cooling, such as described by Kirschner [7, 8]. The teeth to be re-implanted were first extracted, then inserted in the tisa-holdent unit and prepared accordingly.

3. Results

The results of the bending strength tests are summed up by table 1. Assuming an initial value of 600 MPa for polycrystalline aluminum oxide ceramics, only half of this value, i. e. 300 MPa is achieved for monocrystalline ceramics in ground condition. It is only by further surface treatment that high values of bending strength can be achieved, which are typical of monocrystalline ceramics. In the case of polished surfaces these values range at 1.200 MPa, and 1.050 MPa in the case of structured surfaces.

Determinations of the average surface roughness (table 1) showed some interesting differences. After all, the value of 0.5 µm received for ground monocrystalline ceramics was still half as large compared to the value of 1,0 µm obtained for polycrystalline materials. The surface roughness was considerably reduced to 0,02 µm by polishing the surface, which up to now represents the only procedure known for surface treatment. By means of structuring the surface it was possible to obtain an average value of 0,8 µm for the surface roughness, which is nearly equal to the surface roughness of polycrystalline pins.

The clinical application did not cause any problems. With the shrinkage caused by surface treatment being known, it was possible to determine the exact diameter of the pins, thus allowing for the standard instruments to be applied. The high bending strength of the monocrystalline aluminum oxide ceramic pins for the first time allowed for extending the transdental fixation to the cortex of the jaw bone, thus achieving the largest effect possible for this treatment. None of the 20 pins, which had been implanted was rejected. The behaviour of the pins was clinically and radiologically observed and was in correspondence with the behaviour of polycrystalline pins.

The observation period is 18 months. Statistical figures are dispensed with due to the small number of cases and the shortness of the observation period. They will be established later on.

Table 1. Bending strength and average surface roughness of monocrystalline aluminum oxide ceramics

	Bending strength (MPa)	Average surface roughness (µm)
monocrystalline Al_2O_3 ground surface	300	0,5
monocrystalline Al_2O_3 polished surface	1.200	0,02
monocrystalline Al_2O_3 structured surface	1.050	0,8
polycrystalline Al_2O_3	600	1,0

4. Discussion

The high bending strength of polished monocrystalline Al_2O_3-ceramics established by Kawahara (1.300 PMa) could be confirmed almost completely; [6]. As a result it is possible for the first time to apply ceramic pins with relatively small diameters even for transdental fixation far beyond the apex dentis. The structured surface allows for combining the high bending strength of the monocrystalline material with the micro-roughness of the polycrystalline material. In theory the data obtained for the surface structure of polycrystalline material [5] allow for deducing a bone adaptation, which is quite different from what can be achieved with polished monocrystalline material, which was also suggested for transdental fixation [10]. In order to answer the question whether the bone adaptation is influenced by the surface roughness or rather the crystal structure of aluminum oxide, comparative histologic examinations using the four material variations available (rough, polished, monocrystalline, polycrystalline) would be required. The application of monocrystalline aluminum oxide ceramic pins with polished and structured surfaces allows for obtaining high degrees of strength and, as a result, for the use of finer and longer pins, which was not possible in the case of polycrystalline ceramics. Therefore, it is more appropriate for transdental fixation.

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