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The use of ceramic drills on a zirconium oxide basis in bone preparation

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The favourable mechanical properties and high biocompatibility of the newly developed mixed ceramics composed of zirconium oxide and aluminium oxide have continuously extended the scope of their application. Rotating instruments on a zirconium oxide basis are regarded as superior to metal burs in dentoalveolar surgery in terms of favourable temperature effects on the surrounding bone tissue and the economic advantage that they wear slowly, enabling them to be used repeatedly. In this study ten round burs made of zirconium oxide and aluminium oxide mixed ceramics were used for typical dental-alveolar preparation types on an explanted pig jaw. Prior to the first and following the tenth application a scanning electron microscopic (SEM) analysis of possible wear signs was conducted. However, this revealed no evidence of wear or resulting loss of sharpness.

Key words: mixed ceramics, zirconium oxide, rotating instruments, resistance

INTRODUCTION

The recent increasing use of the mechanically and thermally stable zirconium oxide (ZrO_2) high-performance ceramics for drill materials has finally found its way into the surgical disciplines of dentistry after many years of successful use in endoprosthetics for the production of femoral heads [2]. Zirconium oxide, whose flexural strength is superior to that of traditional aluminium oxide ceramics, exists in pure form and as mixed ceramics composed of 80% zirconium oxide and 20% aluminium oxide with improved material properties. The latter exceeds the flexural strength of pure zirconium oxide by a factor of two [4]. Bone cutters and implant drills made of zirconium oxide or advanced hybrid forms of this material are supposed to be superior to steel drills owing to a lower wear-related rise in temperature resulting from high resistance to load and flexural strength [4]. These enhanced properties are assumed to facilitate tissue preservation during drilling, especially in osseous structures. These material-related properties may thus prove advantageous compared to the conventional metal drills used in dental surgical preparations typically for osteotomies of impacted wisdom teeth, root-tip resections or implant site preparation. The aim of this study of rotating instruments made of zirconium oxide and aluminium oxide mixed ceramics was a scanning electron microscopic (SEM) analysis of possible wear signs after repeated use on an explanted pig jaw.

MATERIAL AND METHODS

A total of 10 round burs (Fig. 1) (CAMLOG Biotechnologies, diameter 2.3 mm) made of zirconium oxide and aluminium oxide mixed ceramics were examined *in vitro*, simulating typical dental surgical osteotomies on a fresh explanted pig jaw. The fundamental composition of all drills was examined at

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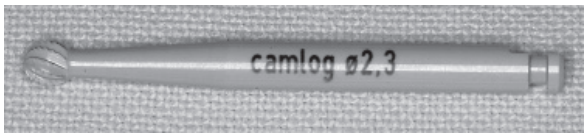

Figure 1. Round bur (CAMLOG Biotechnologies, diameter 2.3 mm) made of zirconium oxide-aluminium oxide mixed ceramics.

one defined site (Fig. 2). According to the manufacturer's specifications, the round drills were used with a 1:1 transmission straight handpiece under NaCl cooling. SEM analyses of each drill were conducted before the first use and after the tenth use respectively for assessment of potential wear signs such as grooves and broken blades.

RESULTS

After a total of 10 usage cycles of each mixed ceramic drill, the trial revealed no fractures whatsoever. No differences in sharpness and cutting performance were subjectively perceived in any round drill after the tenth use in comparison with the first use. Figures 3, 4 and 5 exemplarily show the SEM image (35-fold, 300-fold and 3000-fold enlargements) of a round drill after the tenth use. The 35--fold and 300-fold enlargements of the used round drill clearly reveal the remainders of bone particles (Fig. 3, 4). In comparison with the unused ceramic drill, discreet deburring of the toothed relief in the upper third is observed only rarely both in the 300--fold and 3000-fold enlargements (Fig. 4, 5). Generally, all the SEM images of the used and unused mixed ceramic drills analysed failed to reveal either serious wear signs or fractures within the micro and macro scales. These findings correspond to the impression of the ceramic drills gained clinically.

DISCUSSION

The already enhanced flexural strength of zirconium oxide as compared to conventional ceramics was further increased by the production of zirconium oxide -aluminium oxide mixed ceramics by means of the "hot isostatic pressing" (HIP) sintering process. This amounts to about 2.000 MPA in high-performance ceramics.

Because of its high fracture strength and low fatigue, the outstanding mechanical properties of zirconium oxide, this material has long been used successfully in prosthetic dentistry [4, 8]. The use of these enhanced high-performance and/or mixed ceramics as rotating elements in dental-alveolar surgery was a foreseeable extension of their indication scope,

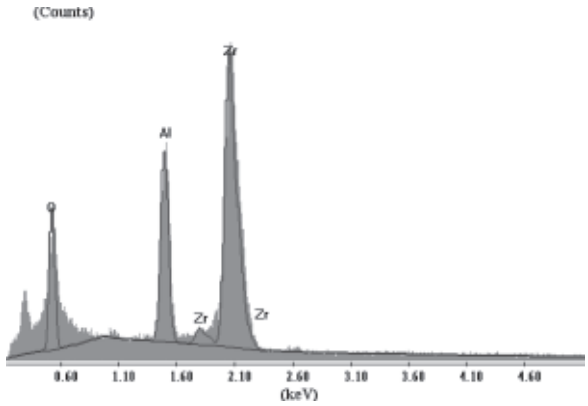

Figure 2. Spectral lines with identified elements.

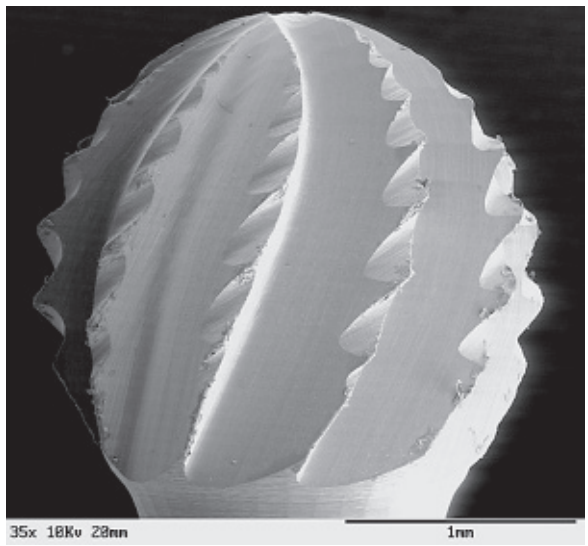

Figure 3. SEM image of a round drill after the tenth use (35-fold enlargement).

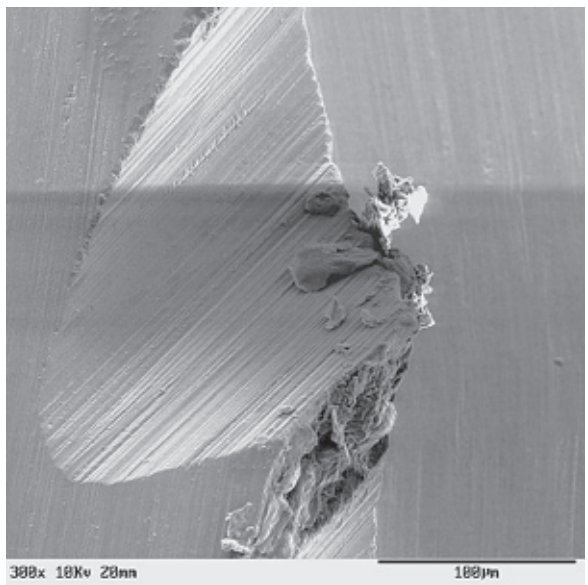

Figure 4. SEM image of a round drill after the tenth use (300-fold enlargement).

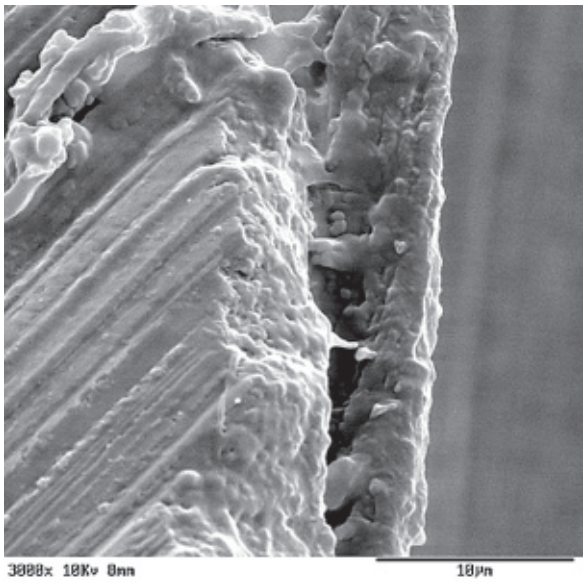

Figure 5. SEM image of a round drill after the tenth use (3000-fold enlargement).

particularly regarding their resistance and low wear after repeated use. The temperatures generated by drilling are a crucial factor for the development of possible bone necroses. Albrektsson and Eriksson [1], who observed bone necroses at temperatures as low as 47 degrees C, clarified the long under-estimated thermosensitivity of osseous structures. Numerous studies reported on the different factors influencing temperature within bony structures during implant site preparation [3, 5]. Apart from drilling pressure and depth, the number of revolutions and the cooling mode and also the drill design and material play important roles. Bone cutters on a zirconium oxide basis can make a pivotal contribution, especially in implantology, to a more gentle surgical technique of implant bed preparation compared to conventional steel cutters. This is due to a decreased wear-related rise in temperature, which inevitably results from the higher pressure components in worn bone cutters after repeated use [6]. In consequence, enhanced primary stability associated with improved osseointegration may thus increase long-term implant success. There are few recent studies describing the use of ceramic drills or bone cutters. Gaertner et al. [4] and Hartmann and Steup [6] found similar results regarding the resistance of ceramic drills after repeated use. In addition, the study of Gaertner et al. [4] found no significant difference in sharpness and wear behaviour between steel and mixed ceramic drills. Furthermore, the biocompatibility of zirconium oxide was rated highly according to a study by Piconi and Maccauro [7], which may be an additional criterion for increased use, together with the economic cost benefit factor resulting from the longevity of resistant material. However, it remains an open question as to how far daily clinical use in contact with porcelain or metallic surfaces during immersion in the drill bath or during sterilisation may yield structural damage, such as microcracks, to the brittle mixed ceramics and so reduce longevity and the number of usages.

CONCLUSION

The newly developed high-performance ceramics on a zirconium oxide basis lend themselves to various applications. Early studies give evidence of their advantageous use as bone cutters. However, their clinical utility has to be confirmed by further studies to justify their routine use in everyday clinical practice.

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