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Dry mechanical-electrochemical polishing of titanium

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Introduction

The post-processing of metallic implants has been given more attention with the continuing rise of additively manufactured (AM) implants. The surface quality of implants is detrimental for the later use since sterilization and cell adhesion prefer certain surface properties.

In response to the growing demand, novel automated methods for electropolishing [1] have entered the market in recent years. One such method is the electro-polishing process known as *DLyte*, used e.g. for 316L stainless steel [2]. The aim of this study is to assess the post-processing quality of this process on AM cranial titanium plates. Foremost, the influence of process times on the roughness was investigated using conventionally produced rods made of titanium.

Materials

Conventionally produced titanium grade 5 rods (Bibus Metals AG) served for the roughness tests. Each rod contained four sections where the surface has been roughened (**black**), rough machined (red), fine machined (blue) or mechanically polished (green) as seen in fig 1. AM cranial titanium plates were manufactured by Selective Laser Melting (SLM) using a SLM Solutions 250^{HL} system (SLM Solutions, Lübeck, Germany). The powder used for this process was titanium grade 2 (Realizer GmbH, Borchen, Germany).

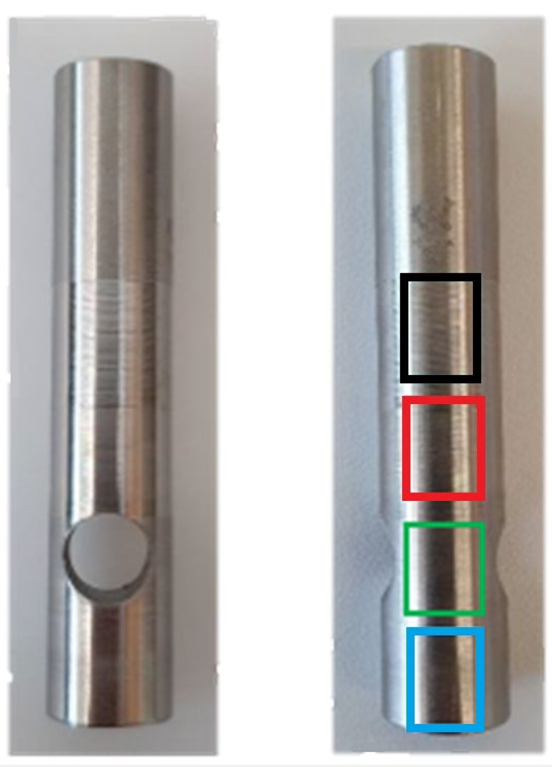

Fig. 1 : Titanium test rods with the four subsections colour coded Ø 12 mm.

Methods

Each manufactured sample was dry electromechanical polished using the DLyte H10 (DLyte, Barcelona, Spain) in combination with DLyte TI MIX acting as the electrolyte. The samples were mounted to metallic specimen holder acting as the anode as seen in fig 2. The samples were then inserted into the polymeric electrolyte and polished for 90 min in total with 15 min processing intervals between analysis. The voltage during the polishing was fixed to 35 V with the polarity as a cyclic factor.

Fig. 2: Holder for the graphite clamping rods (left). Samples inserted in the polymeric electrolyte (right).

For analysis light microscopic (LM) images were recorded using an Olympus SZX10 with 4x magnification and Scanning Electron Microscopy (SEM) images were recorded on a Hitachi TM3030Plus with 80x magnification. The surface roughness was quantified using a Tesa Rugosurf 90 G.

Results

The roughness R_a was lowered significantly throughout all four surface sections of the Ti rods as seen in fig. 3. The R_a value of the fine machined titanium surface was reduced from 0.43 µm to 0.09 µm within 90 min processing time. The polished and rough machined surfaces exposed a similar smoothing trend whereas the roughened surface reduced more linearly from R_a 1.17 µm to R_a 0.77 µm within 90 min treatment.

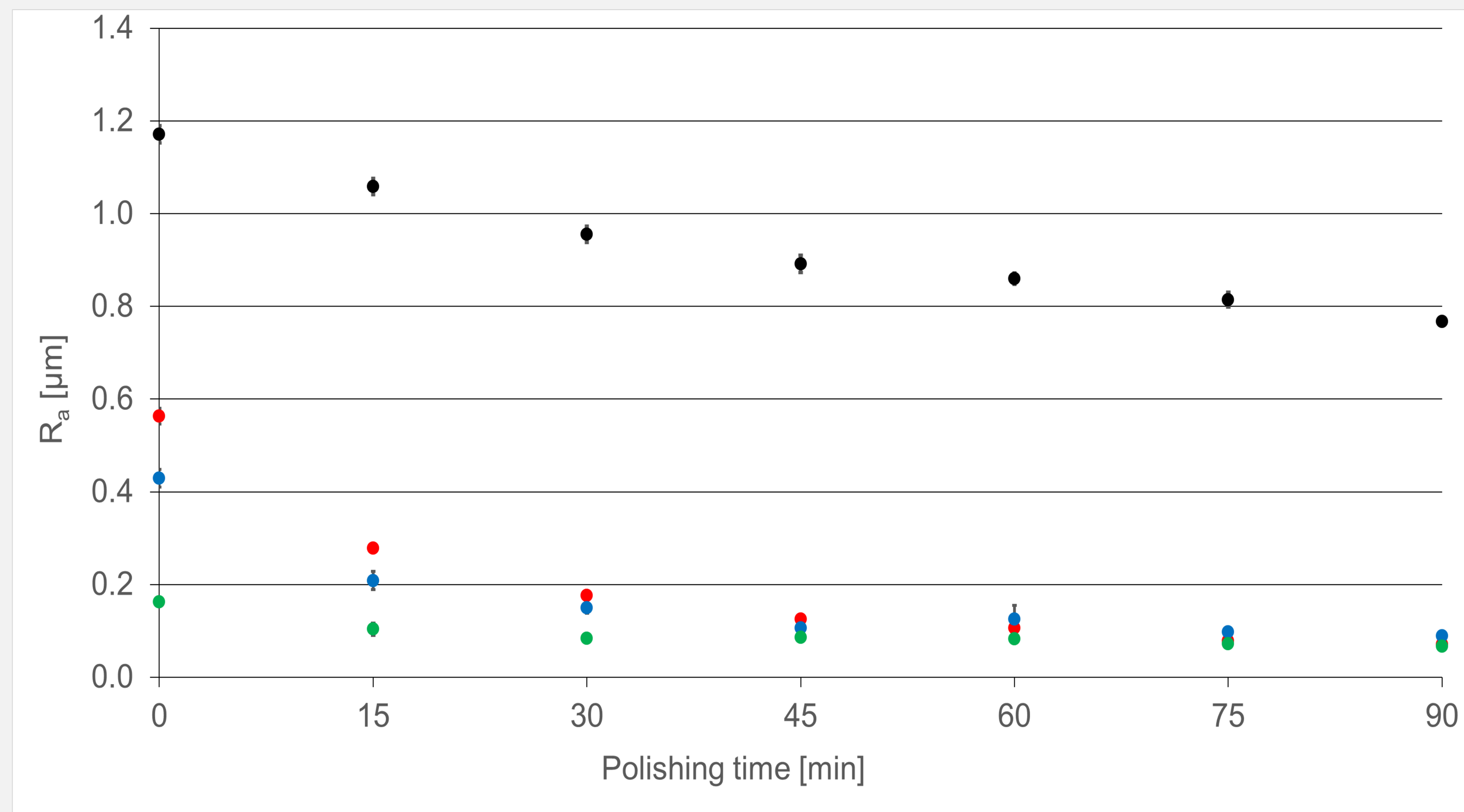

*Fig. 3 : Decrease of R_a as a function of the polishing time of the roughened (**black**), rough machined (red), fine machined (blue) and mechanically polished (green) surface.*

The printed AM cranial plates showed a significantly improved surface quality after polishing as seen in fig. 4. With the DLyte post-treatment the surface of the strut has become overall smoother, shiny and with less cavities.

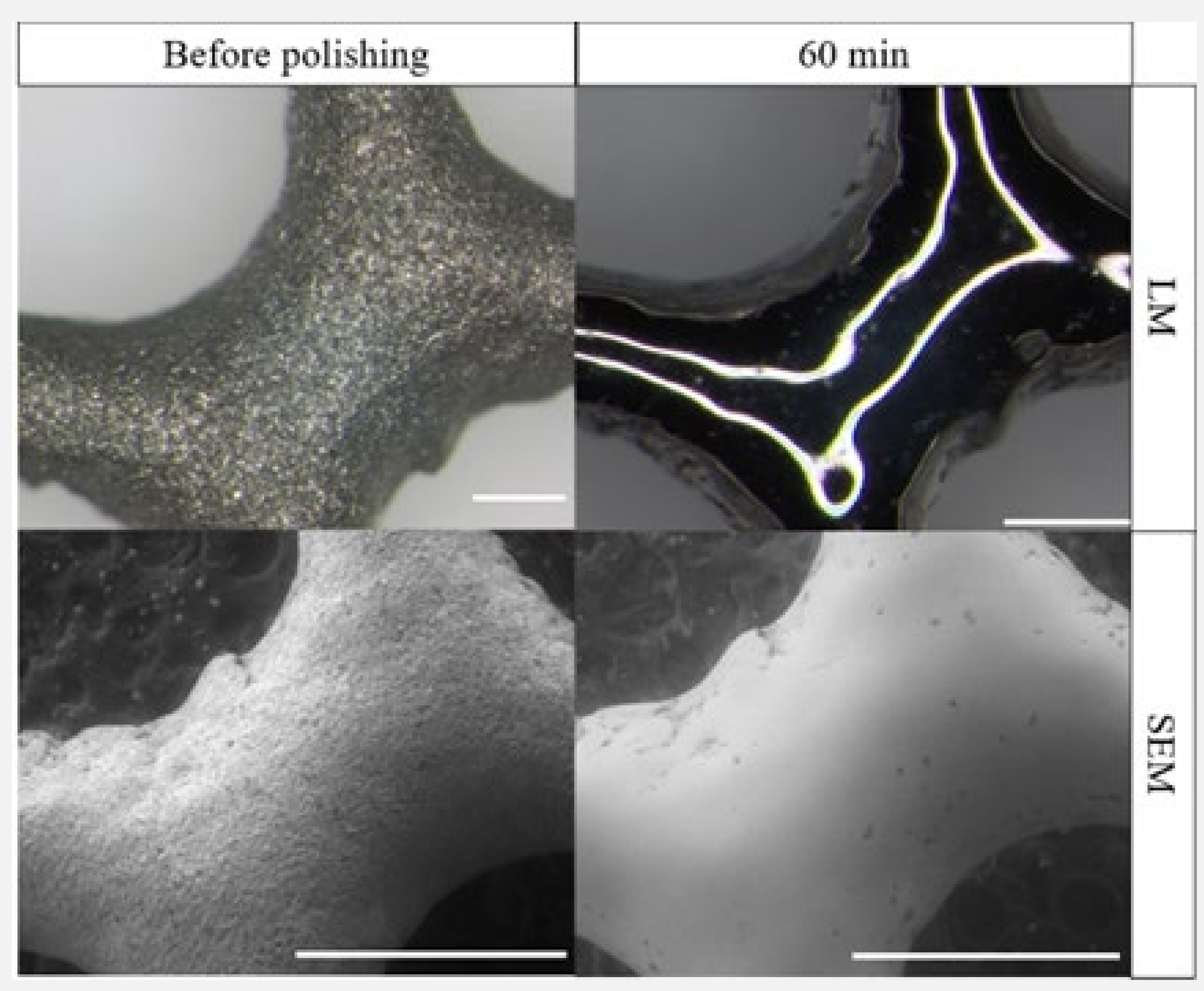

Fig. 4: LM and SEM images of a sandblasted AM titanium strut before polishing (left column) and after 60 min polishing time (right column) (scale 1 mm).

Conclusion

The DLyte technology improved the surface quality of the tested titanium rods significantly after just 15 min of polishing. The surface improvement was especially noticeable in cases where the samples had a low R_a value beforehand. The DLyte process has shown great potential in the post-processing of AM titanium implants even if the structures involves cavities.

References

1 D. Landolt, et al., Electrochimica Acta 48, 3185-3201 (2003).
2 Y. Bai, et al., Materials and Design 193 (2020),