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Analysis of Vector Models in Quantification of Artifacts Produced by Standard Prosthetic Inlays in Cone-Beam Computed Tomography (CBCT) – a Preliminary Study

Analiza modeli wektorowych w ocenie ilościowej artefaktów generowanych przez standardowe wkłady koronowo-korzeniowe w badaniu tomografii stożkowej (CBCT) – doniesienie wstępne

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

Cone-beam computed tomography (CBCT) is a relatively new, but highly efficient imaging method applied first in dentistry in 1998. However, the quality of the obtained slices depends among other things on artifacts generated by dental restorations as well as orthodontic and prosthetic appliances. The aim of the study was to quantify the artifacts produced by standard prosthetic inlays in CBCT images.

The material consisted of 17 standard prosthetic inlays mounted in dental roots embedded in resin. The samples were examined by means of a large field of view CBCT unit, Galileos (Sirona, Germany), at 85 kV and 14 mAs. The analysis was performed using Able 3DDoctor software for data in the CT raster space as well as by means of Materialise Magics software for generated vector models (STL). The masks generated in the raster space included the area of the inlays together with image artifacts. The region of interest (ROI) of the raster space is a set of voxels from a selected range of Hounsfield units (109-3071).

Ceramic inlay with zirconium dioxide (Cera Post) as well as epoxy resin inlay including silica fibers enriched with zirconium (Easy Post) produced the most intense artifacts. The smallest image distortions were created by titanium inlays, both passive (Harald Nordin) and active (Flexi Flange).

Inlays containing zirconium generated the strongest artifacts, thus leading to the greatest distortions in the CBCT images. Carbon fiber inlay did not considerably affect the image quality.

Key words: **cone-beam computed tomography, dental inlays, artifacts**

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List of abbreviations: **CBCT** – cone-beam computed tomography, **ROI** – region of interest, **TMJ** – temporomandibular joint

Introduction

Dental inlays are frequent prosthetic appliances, which allow crown restoration in cases of large loss of hard tissues of teeth. Usually they have been made of metals and their alloys (mainly steel and titanium), but nowadays other non-metallic materials are available for production of the inlays. These materials include glass fibers, carbon fibers, as well as ceramic materials or resins containing zirconium [5].

Cone-beam computed tomography (CBCT) is an imaging method applied first in dentistry in 1998. Since then the number of performed CBCT examinations in dentistry has been constantly growing. The indications are numerous, e.g. planning of implant placement as well as follow-up, imaging of congenital dental and maxillofacial abnormalities, endodontics, dental and maxillofacial trauma as well as temporomandibular joint (TMJ) disorders or periodontology. It is believed that in a few years time CBCT will become a gold standard in dentomaxillofacial imaging. However, the quality of the obtained slices depends among other things on artifacts generated by dental restorations as well as orthodontic and prosthetic appliances. In patients with fewer restorations and fixed appliances, the quality of image will be higher and this may influence the diagnosis. When more fixed appliances are present in the oral cavity, the diagnosis may be compromised [4,7].

The aim of the study was to quantify the artifacts produced by standard prosthetic inlays in CBCT images.

Materials and methods

The material consisted of seventeen standard prosthetic inlays mounted in dental roots embedded in resin.

The material included:
- 9 titanium inlays (pure or alloys), active and passive: Flexi Post, Opti Post, Para Post, Vario Post, Harald Nordin, Flexi Flange, Cytco K, Unimetric, Radix Anker;
- 1 carbon fiber inlay: Carbonite;
- 3 glass fiber inlays: Para Post Fiber White, Glassix, Hahenkraft;
- 2 steel inlays: Dentex, Stomed;
- 1 ceramic with zirconium dioxide: Cera Post;
- 1 epoxy resin with silica fibers enriched with zirconium: Easy Post.

The samples were examined by means of a large field of view CBCT unit, Galileos (Sirona, Germany), at 85 kV and 14 mAs [Fig. 1]. The voxel size was 0.286 mm. The study objects were placed within the center of the imaged volume in a standardized manner.

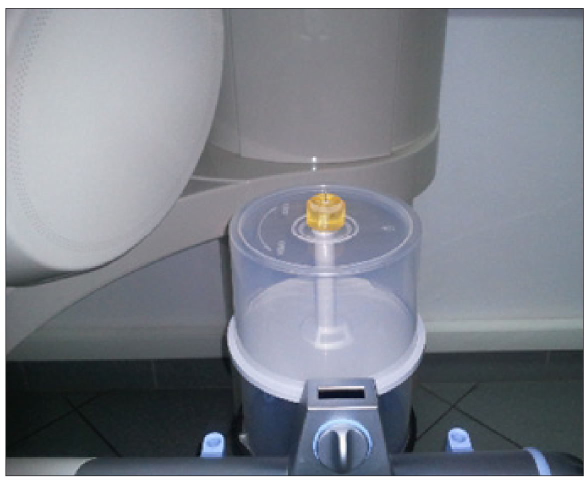

Fig. 1. Inlay mounted in resin in CBCT machine

The examinations were stored as standard DICOM files and used for computer analysis. The analysis was performed using Able 3DDoctor software for data in the CT raster space as well as by means of Materialise Magics software for generated vector models (STL). The masks

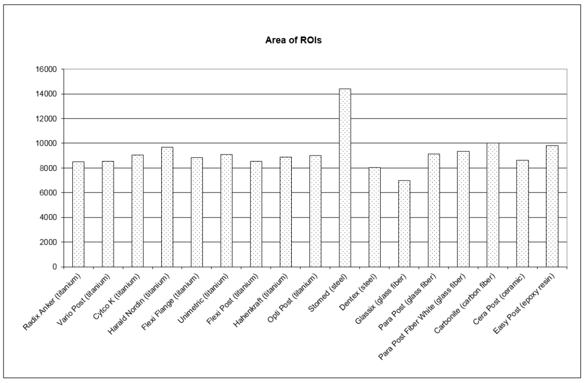

Fig. 2. Area of ROIs

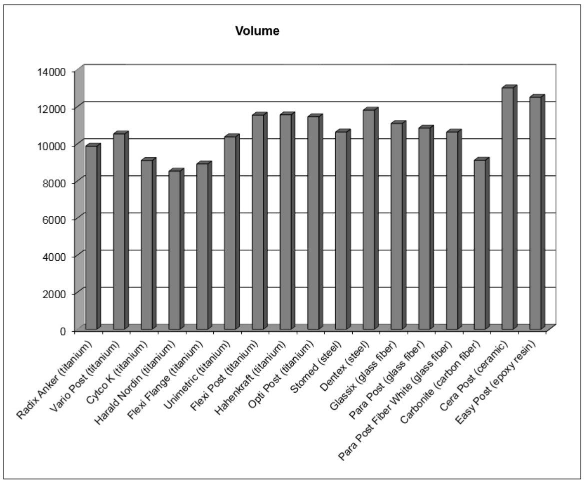

Fig. 3. Volume of ROIs

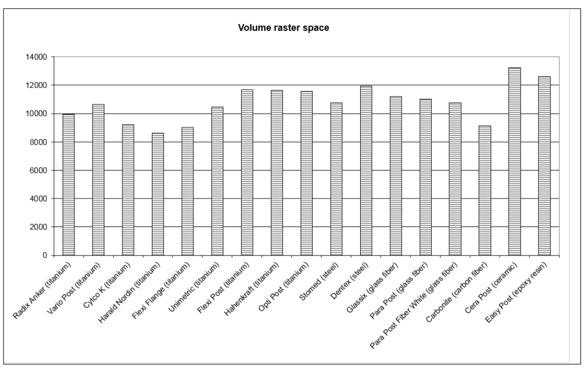

Fig. 4. Volume of ROIs in the raster space

generated in the raster space included the area of the inlays together with image artifacts. The region of interest (ROI) of the raster space is a set of voxels from a selected range of Hounsfield units (109-3071).

The volumes of generated vector models correspond to volumes of masks in the CT raster space. It confirms the accuracy of conversion of CBCT image data to vector models. Any differences are due to interpolation of the surface of vector models. When exposure parameters are constant, it is the scanned material that mostly influen-

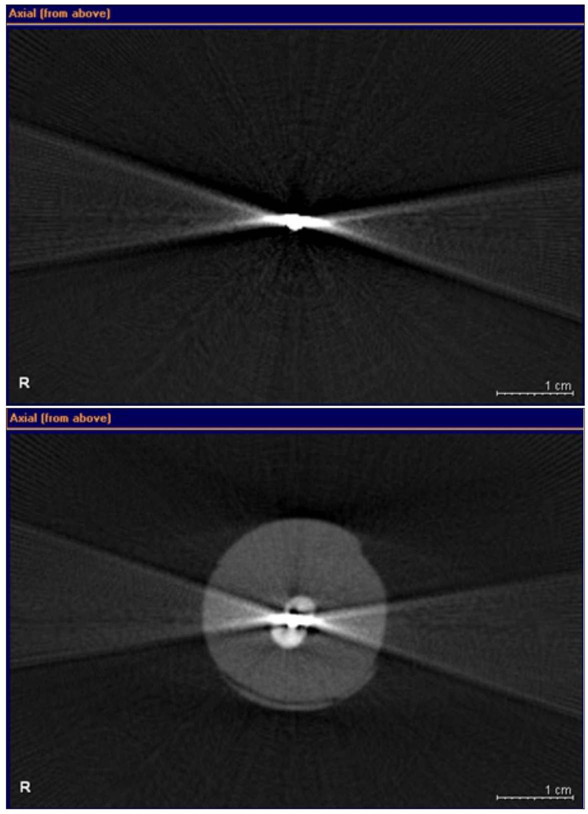

Fig. 5. Artifacts created by a ceramic inlay at the level of the inlay (A) and at the level of the dental root (B)

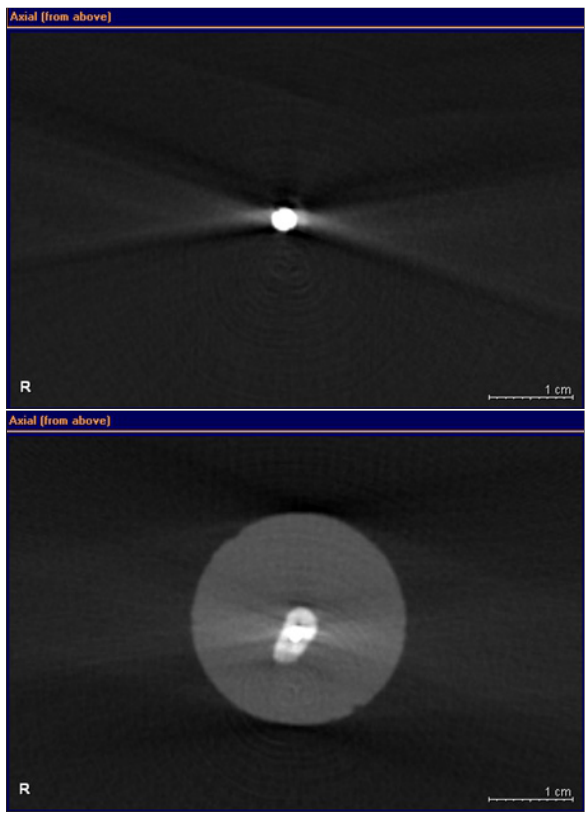

Fig. 6. Artifacts created by a titanium inlay on the level of the inlay (A) and on the level of dental root (B)

ces the appearance of image artifacts. On this basis of the vector analysis it is possible to determine intensity and type of occurring artifacts.

Results

The results are presented in figures 2 to 4 [Fig. 2, 3 and 4]. Ceramic inlay with zirconium dioxide (Cera Post) [Fig. 5A, B] as well as epoxide resin inlay including silica fibers enriched with zirconium (Easy Post) produced the most intense artifacts. The smallest image distortions were created by titanium inlays, both passive (Harald Nordin) and active (Flexi Flange) [Fig. 6A, B].

Discussion

The quality of CBCT images is influenced by artifacts, which are caused mainly by the beam-hardening effect (i.e. lower energy photons absorbed in preference to higher energy photons) and appear as streaks and dark bands. Another type of artifacts is the so-called cupping artifacts, which are caused by beam hardening and scatter. The artifacts reduce the sensitivity and specificity of the CBCT technique, e.g. in evaluation of root canal anatomy or detecting root fractures [6,8].

Voxel size is related to the contrast and resolution of CBCT images. In general artifacts are specific to a CBCT unit type – in some machines small voxel size reduces artifacts, while in others it can increase the background noise and thus degrade the image quality. A combination of large field of view CBCT with a small voxel size increased the presence of metallic artifacts and negatively influenced the diagnosis of horizontal root fractures in a study by Costa et al. [3].

Brito-Junior et al. studied the effects of different root canal sealers on detection of root fractures in CBCT [1]. They found that streaking artifacts were produced by all examined root canal sealers, mainly when a 0.20 mm voxel size was used. They concluded that the use of a smaller voxel size was preferable to reduce the presence of artifacts and to improve the diagnostic accuracy of root fractures in root filled teeth.

In another study, Costa et al. tested the accuracy of small-volume CBCT scanning in the detection of horizontal root fractures and to assess the influence of a metallic post [2]. Small-volume CBCT scanning showed high accuracy in detecting horizontal root fracture without a metallic post. However, the presence of a metallic post significantly reduced the specificity and sensitivity of this examination.

In our own study the type of inlay material influenced the severity of artifacts. Ceramic inlay with zirconium dioxide (Cera Post) produced the most intense artifacts. The smallest artifacts were generated by carbon fiber inlay (Carbonite). Small image distortions were created by titanium inlays, both passive (Harald Nordin) and active (Flexi Flange).

Conclusions

Inlays containing zirconium generated the strongest artifacts, thus leading to the greatest distortions in the CBCT images.

Carbon fiber inlay did not considerably affect the image quality.

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