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ORIGINAL ARTICLE / ARAŞTIRMA MAKALESİ

Evaluation of Artifacts Produced by Different Dental Crown Materials on Ultrashort Echo Time Magnetic Resonance Imaging

Farklı Dental Kron Materyalleri Tarafından Üretilen Artefaktların Ultrashort Echo Time Manyetik Rezonans Görüntüleme Üzerinde Değerlendirilmesi

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ABSTRACT

Objectives: Many patients with metallic objects in the head and neck region may require magnetic resonance imaging (MRI).The aim of this study was to assess the artifacts produced by different dental crown materials on ultrashort echo time (UTE) MRI.

Materials and Methods: Cobalt-chromium (Co-Cr) and zirconia (Zr) crown and fixed bridges were included and embedded in agar gel. UTE sequence by 1.5T MRI was performed and the artifact area produced by these materials, were measured within the region of interest (ROI). Mean artifact areas were recorded.

Results: Mean artifact area produced by Co-Cr and Zr was 140.055 mm^2 and 102.349 $mm^{2,}$ respectively. Zr material produced less artifacts than metal restoration. It was stated that the amount of artifact increased as the number of elements increased.

Conclusions: Co-Cr metal restorations have stronger effect than Zr material on UTE MRI. UTE sequence is useful in evaluating susceptibility artifacts from different materials. Knowing the amount of artifact produced by different materials will help to produce new materials that cause less artifact formation or to improve the properties of existing materials.

Keywords: Artifacts, Dental materials, Dental restoration, Magnetic Resonance Imaging, UTE

ÖZ

Amaç: Baş ve boyun bölgesinde metalik nesneler bulunan birçok hastada manyetik rezonans görüntüleme (MRG) gerekebilir. Bu çalışmanın amacı, ultrashort echo time (UTE) MRG'de farklı dental kron materyalleri tarafından üretilen artefaktları değerlendirmektir.

Gereç ve Yöntemler: Kobalt-krom (Co-Cr) ve zirkonyum (Zr) kron ve sabit köprüler dahil edildi ve agar jele gömüldü. 1.5T MRG ile UTE sekansı yapıldı ve bu materyallerin ürettiği artefakt alanı, ilgilenilen bölge içinde ölçüldü. Ortalama artefakt alanları kaydedildi.

Bulgular: Co-Cr ve Zr tarafından üretilen ortalama artefakt alanı sırasıyla 140.055 mm^2 ve 102.349 mm^2 idi. Zr materyali metal restorasyondan daha az artefakt üretti. Element sayısı arttıkça artefakt miktarının da arttığı belirtildi.

Sonuçlar: Co-Cr metal restorasyonlar UTE MRG'de Zr materyalden daha güçlü etkiye sahiptir. UTE sekansı, farklı materyallerden duyarlılık artefaktlarının değerlendirilmesinde yararlıdır. Farklı materyallerin ürettiği artefakt miktarının bilinmesi, daha az artefakt oluşumuna neden olan yeni materyallerin üretilmesine veya mevcut materyallerin özelliklerinin iyileştirilmesine yardımcı olacaktır.

Anahtar Kelimeler: Artefaktlar, Dental materyaller, Dental restorasyon, Manyetik Rezonans Görüntüleme, UTE

INTRODUCTION

The increase in indication for magnetic resonance imaging (MRI) of the head and neck area is associated with a large number of patients who have metallic objects in the orofacial region such as dental crowns, fixed bridges, splints and implants, surgical fixtures and clips (Starcuková et al., 2008). Crowns, bridges and implants are common fixed prostheses that have been the main treatment choices in prosthetic dentistry (Saeed et al., 2020).

MRI generates images with using a strong uniform static magnetic field and radiofrequency pulses. When materials are placed in a magnetic field, they are magnetized to some extent depending on their magnetic susceptibility (Gray et al., 2003;Czervionke et al., 1988). As an undesirable, changes in magnetic field strength at the interface between dental materials and neighboring tissue may cause to spatial distortions and signal loss, producing an image artifact (Fache et al., 1987).The amount of artifact varies depending on the shape, orientation, location, and number of objects in or near the imaged volume with the magnetic field strength of the

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scanner, pulse sequence type, and pulse sequence parameters (Schenck, 1996; Bui et al., 2000; Hubálková et al., 2002).

Conventional MRI provides a non-invasive evaluation of soft tissue protons and avoids the potential harm related with x-ray imaging modalities. But, cortical bone has a short transverse relaxation time (T2 star), making it invisible when studied with conventional clinical MRI sequences with echo times of a few milliseconds or longer (Robson et al., 2003; Reichert et al., 2005). The absence of direct signal from bone makes it impossible to measure MRI relaxation times (eg, T1 and T2 star), magnetization transfer rate, and volume concentration of several bone compartments. To address this insufficiency and to take advantage of both the safety profile of MRI and the perfect evaluation of soft tissues such as muscle, a benefit not found in modalities with x-ray, some advanced MRI modalities have newly been developedfor assessment bone more effectively (Du & Bydder, 2013; Chang et al., 2015; Manhard et al., 2017; Wehrli, 2013). One of them, ultrashort echo time (UTE) MRI on the order of microseconds allows direct imaging and quantitative evaluation of cortical bone (Du & Bydder, 2013).

The aim of this study was to measure the amount of artifacts produced by different dental crown materials on UTE sequence. The first null hypothesis was that the area of artifact would be larger in cobalt-chromium (Co-Cr) restorations than zirconia (Zr) restorations. The second null hypothesis was that the area of artifact would be larger as the number of members increased in both Co-Cr and Zr restorations.

MATERIALS AND METHODS

In terms of adaptation of the study results to clinical practice, crowns and bridges that exactly reflect the patient's dental arch and which were removed within the indication were used. One single dental crown, one three and five-element fixed bridge made of Co-Cr and Zr were included in this study. The composition of the metal restorations consisted predominantly of cobalt (62%) and chromium (27%). This was followed by molybdenum with a rate of 6%.

A rectangular plastic container was used to prepare the phantom of this study. First, the first layer of 1% hot agar in water was poured into the plastic container to fill half the volume of container. The container was covered with cling film and left at room temperature for 30 minutes to gel. Samples were attentively placed on top of the solid first agar gel layer to provide that all objects could be scanned on the same slice. In the continuation, a second agar solution was prepared and poured attentively to fill the container so as not to disturb the sequencing of the samples.

1.5 T MRI device (Magnetom Siemens Altea, Germany) was used for the phantom scanning. Imaging parameters were 230x230FOV, slice thickness of 1 mm, number of slices 256,TE-0.07, bandwidth of 635 Hz/Px, flip angle 10^0 (Table 1).

Table 1. Imaging parameters used in this study

Sequence	Strength	FOV (mm)	Slice thickness (mm)	Slice numbers	Bandwidth (Hz/Px)	TE (ms)	Flip angle (°)
UTE	1.5T	230x230	1	256	635	0.07	10

Images were acquired at UTE sequence. After the phantom was scanned, it was saved as digital imaging and communications in medicine (DICOM) files. DICOM files were opened with the RadiAnt DICOM Viewer (64-bit) software (Medixant Company, Poland) and saved as screenshots. These images were transferred in ImageJ® (National Institute of Health, Bethesda, MD, USA). Based on the study of Gao et al. (2022) and Cortes et al. (2015), artifact measurement of all specimens, was performed. Artifacts were defined as signal intensity and signal loss adjacent to the prosthesis, and measurement of these areas was made in the same horizontal plane by plotting the region of interest (ROI) around the restorations. After the ROI is determined, Image-Adjust-Threshold tabs were used through the software program. The threshold was determined considering the signal intensities histogram (8-bit pixel values). A lower threshold valueof zero and a higher threshold value of 121 were determinedand applied for all measurements. Afterwards, measurements were performed and recorded using the Analyze-Measurement tabs (Figure 1). All measurements were done by a calibrated observeron the same laptop to rule out changes in image resolution (Dell Inc., Round Rock, TX, USA).Undecided situations were solved by consensus with the authors. Image manipulation was not allowed using the development tools of the tracer solution (magnification, contrast, brightness).The average artifact areas of each specimen were recorded in an excel file. Descriptive statistics were used in the analysis of the obtained data.

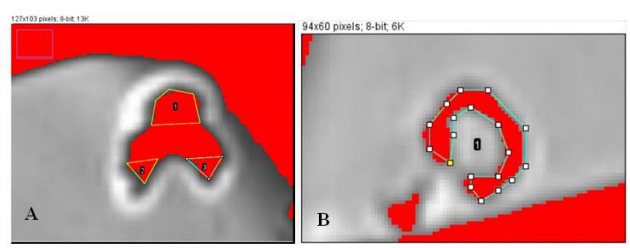

Figure 1. The artifact measurement of single crown. A. Cobalt – chromium B. Zirconia

RESULTS

The mean artifact area of Co-Cr one single dental crown, one three and five-element fixed bridge was 31.195, 173.844 and 215.125 mm^2, respectively while of Zr one single dental crown, one three and five-element fixed bridge was 24.186, 100.516 and 182.344 mm^2, respectively (Table 2). Zr material produced less artifacts than Co-Cr restoration. It was stated that the amount of artifact increased as the number of elements increased.

Table 2. The mean artifact areas according to the element number of different materials

The mean artifact areas (mm^2)					
Cobalt-chromium restorations			Zirconia restorations		
Single crown	Three element fixed bridge	Five element fixed bridge	Single crown	Three element fixed bridge	Five element fixed bridge
31.195	173.844	215.125	24.186	100.516	182.344

DISCUSSION

In this study, the effect of different dental restoration materials and restoration element numbers on the size of the artifact area in UTE-MRI sequences was evaluated. The first null hypothesis was accepted due to increase in artifact area in Co-Cr restorations. The second null hypothesis was accepted due to the increase in artifact area as the number of restoration elements increased.

Decreased image quality and image distortions caused by various metal restorations and prostheses make image interpretation and diagnosis difficult. This may limit the use of CT and MRI imaging (Klinke et al., 2012). In this study, Co-Cr supported restorations and Zr restorations, which are one of the most commonly used alloys in prosthetic dentistry, were used. Due to their frequent use, it was hypothesized that the amount of artifact they would produce could be considered in the selection of prosthetic restorations.

Gao et al. (2022) reported that Co-Cr single crown produced between 31.833 mm^2 and 44.616 mm^2 artifacts around teeth and double Co-Cr crowns increased artifact areas by 150.10 mm^2.The result of this study was found close to the lower value reported by Gao et al. (2022). The difference in artifact area between Co-Cr single crown and three element fixed bridge was 142.649 mm^2.

Tymofiyeva et al. (2013) reported that Co-Cr had the strongest distortion and were stated as non-compatible. However, Zr was classified as compatible material. Similarly, this study showed that Co-Cr metal restorations have stronger artifact effect. Consistent with this study, Hilgenfend et al.(2016) reported that Zr implant with monolithic Zr crown produced less artifact on MRI.

As the size of the material increases, the size of the artifact will also increase. When the material is within a radius of 10 cm inside the ROI, there will be a maximum area of signal loss. Artifacts are seen even in paramagnetic metals and the causative factor is related to the shape of the material (Taniyama et al., 2010).This explains the increase in the artifact area as the number of restoration elements increases, which is revealed in this study.

Advanced MRI techniques such as slice coding for metal artifact correction (SEMAC) and multi-acquisition variable resonance image combination (MAVRIC) have been proposed to decrease metal artifacts around the metal restorations The SEMAC array is reduction of metal artifact MRI procedure based on 2D viewing angle tilt (VAT) and may supply robust coding of slices stimulated against metal-induced field inhomogeneities within an appropriate scan time. By combining data analyzed from multiple slices corrected by SEMAC and using VAT, SEMAC may be used to correct for spatial distortions (Klinke et al., 2012).

In this study, a special sequence UTE was preferred. Reichert et al.(2005) reported that UTE is the most indicated sequence to observe solid structures, and two studies (Bracher et al., 2013; Hövener et al., 2012) have reported UTE as useful sequence to distinguish the oral tissues and make diagnosis.Relatively small fields of artifacts in both 1.5 and 3.0 T, very short echo times that maintain satisfactory contrast resolution, and the use of high bandwidth values are cited as reasons why UTE has these advantages (Cortes et al., 2015). In the study of Cortes et al.(2015), the mean artifact area was reported as 6.74 cm^2 for UTE images. The smallest artefact area was obtained using UTE sequence at 1.5 T. Abdala Junior et al.(2021) evaluated the artifact caused by orthodontic appliances composed of different alloys and also reported that UTE sequences produced smallest artifact areas.

CONCLUSION

Co-Cr metal restorations produced larger artifact areas than Zr material on UTE MRI. UTE sequence is useful in evaluating susceptibility artifacts from different materials. In 2015, Cortes et al. (2015) reported that their study was the first to investigate the effectiveness of the UTE sequence in generating images with small-size MRI metal-ceramic artifacts. Therefore, it can be said that the UTE related to this subject is novel sequence in the literature. Along with this study, future studies will contribute to the literature.

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Conflicts Of Interest Statement

There is no conflict of interest for this study.

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