UDK 616-76:537.622
Original scientific article/Izvirni znanstveni članek

ISSN 1580-2949
Mater. Tehnol.

QUANTITATIVE MEASUREMENT OF MAGNETIC FORCE IN BASIC AND PRECIOUS DENTAL ALLOYS FOR PORCELAIN TECHNIQUE

KVANTITATIVNO MERJENJE MAGNETNE SILE NA OSNOVNIH IN PLEMENITIH ZOBNIH ZLITINAH ZA PORCELANSKO TEHNIKO

Peter Majerič[1,2,3], Milan Svetec[3], Peter Mihor[3], Zvonko Jagličić[4], Aleksandra Kocijan[5], Rebeka Rudolf[1,2,3*]

[1]University of Maribor, Faculty of Mechanical Engineering, Maribor, Smetanova ul. 17, Slovenia
[2]Zlatarna Celje d.o.o., Kersnikova ul. 19, Celje, Slovenia
[3]Jožef Stefan Institute, Jamova 39, Ljubljana, Slovenia
[4]Institute of Mathematics, Physics and Mechanics & University of Ljubljana, Faculty of Civil and Geodetic Engineering, Jadranska 19, Ljubljana, Slovenia
[5]Institute of Metals and Technology, Lepi pot 11, Ljubljana, Slovenia

Prejem rokopisa – received: 2026-03-04; sprejem za objavo – accepted for publication: 2026-04-24

doi:10.17222/mit.2026.1679

Precious dental alloys based on gold, platinum, palladium or silver exhibit excellent corrosion resistance, high biocompatibility and optimal mechanical properties for use in prosthetic dentistry. In comparison, base dental alloys based on chromium, cobalt or nickel are cheaper, have excellent mechanical properties but poorer corrosion resistance and biocompatibility. This research examined the magnetic properties of dental alloys in a magnetic field, which vary with composition and electronic structure. Materials can be classified as diamagnetic, paramagnetic or ferromagnetic, depending on how they respond to an external magnetic field, with noble metals usually showing weak or negligible magnetic behaviour. Experimental results of magnetic force measurements in precious dental alloys have shown that most exhibit diamagnetic properties, being weakly repelled by a magnetic field, and do not retain any magnetization when the magnetic field is removed. One of the tested precious-metal alloys exhibited paramagnetic behaviour, indicating a weak attraction in a magnetic field. In contrast, all studied dental base-metal alloys exhibited stronger paramagnetic interactions with magnetic fields. Diamagnetic properties of precious-metal dental alloys present a significant advantage in the medical environment, especially in magnetic resonance imaging (MRI) as diamagnetic materials do not interfere with magnetic fields and thus reduce image distortion and patient risk during MRI. However, paramagnetic base-metal dental alloys can cause local heating or imaging artefacts under MRI conditions. Therefore, precious-metal dental alloys are more suitable for patients who may require MRI, as they combine functional durability with greater safety in medical diagnostics.

Keywords: base and noble dental alloys, magnetic force, magnetic resonance imaging safety, characterization

Plemenite zobne zlitine na osnovi zlata, platine, paladija ali srebra imajo odlično korozijsko odpornost, visoko biokompatibilnost in optimalne mehanske lastnosti za uporabo v protetični stomatologiji. V primerjavi z njimi so osnovne zobne zlitine na osnovi kroma, kobalta ali niklja cenejše, z odličnimi mehanskimi lastnostmi, vendar slabšo korozijsko odpornostjo in biokompatibilnostjo. V tem članku avtorji opisujejo raziskavo, ki je preučevala magnetne lastnosti zobnih zlitin, ki se razlikujejo glede na sestavo in elektronsko strukturo. Materiale lahko razdelimo na diamagnetne, paramagnetne ali feromagnetne, glede na to kako se odzivajo na zunanje magnetno polje, pri čemer plemenite kovine običajno kažejo šibko ali zanemarljivo magnetno obnašanje. Eksperimentalni rezultati merjenja magnetne sile v plemenitih zobnih zlitinah so pokazali, da večina kaže diamagnetne lastnosti, kar pomeni, da jih magnetno polje šibko odbija in da ne ohranijo nobene magnetizacije, ko je magnetno polje odstranjeno. Ena od testiranih plemenitih zlitin je pokazala paramagnetno obnašanje, kar kaže na šibko privlačnost v magnetnem polju. Nasprotno pa so vse raziskane osnovne (bazne) zobne zlitine pokazale močnejše paramagnetne interakcije z magnetnimi polji. Diamagnetne lastnosti plemenitih zobnih zlitin predstavljajo pomembno prednost v medicinskem okolju, zlasti pri slikanju z magnetno resonanco (MRI), saj diamagnetni materiali ne motijo magnetnih polj in s tem zmanjšujejo popačenje slike in tveganje za paciente med slikanjem z magnetno resonanco. Paramagnetne bazne zobne zlitine pa lahko v pogojih slikanja z magnetno resonanco povzročijo lokalno segrevanje ali slikovne artefakte. Zato so plemenite zobne zlitine primernejše za paciente, ki potrebujejo slikanje z magnetno resonanco, saj združujejo funkcionalno vzdržljivost z večjo varnostjo v medicinski diagnostiki.

Ključne besede: bazne in plemenite dentalne zlitine, magnetna sila, varnost slikanja z magnetno resonanco, karakterizacija

1 INTRODUCTION

Magnetic resonance imaging (MRI) has become one of the most important diagnostic tools in modern medicine due to its ability to produce high-resolution images of anatomical structures. Its high soft-tissue contrast, multiplanar capability, sensitivity, and non-invasive nature have made MRI indispensable in evaluating the central nervous system, musculoskeletal structures, vascular anomalies, and soft-tissue tumours.[1,2] In the craniomaxillofacial region, MRI is widely used for diagnosing temporomandibular joint disorders, tumours, vascular

*Corresponding author's e-mail:
rebeka.rudolf@um.si (Rebeka Rudolf)

malformations, and soft-tissue pathologies, and it provides valuable information for treatment planning and therapy monitoring.[3,4] Increasing accessibility and safety, together with superior soft-tissue visualization, have contributed to the growing use of MRI worldwide.

Metallic restorations are frequently used in prosthetic dentistry, used for crowns, bridges, splints, orthodontic appliances, endosseous implants, and fixation devices. These devices are commonly manufactured from precious-metal alloys (gold, platinum, palladium, and silver), base-metal alloys (cobalt, chromium, and nickel), titanium, dental amalgam, or stainless steel. These materials are also veneered with composites or ceramics for an added aesthetic function. Precious dental alloys exhibit excellent corrosion resistance due to their chemical stability and low reactivity in the oral environment.[5] They resist oxidation and degradation when exposed to saliva, fluctuating pH, dietary acids, and temperature changes. In contrast, base-metal alloys rely on the formation of passive oxide layers for protection.[6] Although these oxide films can provide adequate corrosion resistance, they may be compromised under acidic or highly variable oral conditions, potentially leading to ion release and surface degradation over time. As a result, precious alloys generally demonstrate superior long-term chemical stability compared with base-metal dental restorations.[5]

Biocompatibility is another critical factor in the selection of dental materials. Precious-metal alloys are highly biocompatible because they release minimal ions and rarely provoke adverse tissue reactions. Their chemical inertness reduces the risk of hypersensitivity, inflammation, and cytotoxic effects, making them especially suitable for patients with metal sensitivities or complex medical histories.[7] Base-metal alloys, while generally safe for clinical use, may release nickel, chromium, or cobalt ions, which in susceptible individuals can trigger allergic reactions, mucosal irritation, or localized inflammatory responses.[8,9] Consequently, precious alloys are often preferred in situations where optimal tissue compatibility is essential.

The longevity of precious-metal dental alloys is closely linked to their corrosion resistance, structural stability, and favourable mechanical behaviour. Their resistance to tarnish and degradation helps maintain marginal integrity, surface smoothness, and functional performance over extended periods, often resulting in restorations that remain serviceable for decades.[10] Base-metal alloys provide high strength and rigidity at lower cost, making them suitable for many prosthetic applications; however, their long-term performance may be influenced by corrosion processes, oxide layer breakdown, or biological responses in the surrounding tissues.[8,9] Overall, precious-metal alloys are widely regarded as the benchmark for durability and long-term clinical success, whereas base-metal alloys offer a cost-effective alternative with acceptable, though sometimes less predictable, longevity.

As dental patients are increasingly referred for MRI examinations for medical indications, the interaction between these metallic materials and magnetic fields has become a clinically relevant aspect to consider. As different metals and alloys have different responses in a magnetic field, the metallic dental restorations can influence MRI performance by producing image artefacts, local heating, or magnetic field distortions.[11] There were also cases in which dental restorations (such as dental crowns) bacame dislodged in a patient's mouth during an MRI scan.[3,12]

MRI operates using a strong magnetic field and radiofrequency pulses, causing materials to become magnetized according to their magnetic susceptibility. Generally, substances may be classified as diamagnetic, paramagnetic, or ferromagnetic depending on their response to magnetic fields.[1,2] Differences in magnetic susceptibility at the interface between dental materials and surrounding tissues may produce image artefacts, signal loss, and geometric distortions. In addition to image degradation, MRI-related interactions with metallic dental materials may lead to radiofrequency-induced heating or magnetically induced displacement forces.[3,11] Local heating is, however, mainly a byproduct of currents flowing in the RF field of the magnet. It is influenced by the conductivity of the alloy. Pauli paramagnetism is not uniquely related to conductivity. There are materials that are good conductors but have a low Pauli susceptibility (e.g. copper, which is diamagnetic). Previous studies indicate that ferromagnetic and some base-metal alloys can cause significant artefacts or safety concerns, whereas precious-metal alloys and titanium generally produce

Table 1: General overview of dental materials, their magnetic properties and compatibility with MRI[3,11]

Dental material type	Magnetic behaviour	Compatibility with MRI	MRI interference
Glass ionomers, resin, zirconium dioxide, feldspar, some composites	Low/weak susceptibility, diamagnetic, paramagnetic	Compatible	No image artefact or distortion
Amalgam, high-gold noble alloys, semi-precious alloys, titanium	Low/weak susceptibility, diamagnetic, paramagnetic	Compatible	Less likely to cause an artefact or image distortion
Stainless steel, cobalt-chrome alloys	Higher susceptibility, paramagnetic, ferromagnetic	Non-compatible	High potential for artefacts, significant image distortions, even when imaging regions are located far from the material

fewer distortions and demonstrate greater compatibility with MRI environments. Pauli paramagnetism, however, is of a similar order of magnitude to diamagnetism. Neither causes significant imaging artifacts. Only in the case of paramagnetism associated with localized magnetic moments (Curie type: 1/*T* dependence) does this phenomenon cause inhomogeneous distortion of the magnetic field and affect image quality. Paramagnetic base alloys are usually also good conductors. The general impact of typical dental materials on MR image artefacts are known (**Table 1**), while comprehensive data regarding the magnetic behaviour of specific dental casting alloys with varying compositions remain limited.

Diamagnetic substances have no unpaired orbital electrons and, when placed in an external magnetic field, develop a weak induced field in the opposite direction, resulting in a small negative magnetic susceptibility and essentially non-magnetic behaviour (e.g., copper, gold, zinc, lead, carbon, bismuth). Paramagnetic substances generate an induced magnetic field in the same direction as the external field, increasing the effective magnetic field (e.g., chromium, manganese, aluminium). They may contain atoms with unpaired electrons that produce a non-zero atomic magnetic moment (localized magnetic moments), or their paramagnetism may arise from the behaviour of the conduction electrons. Localized paramagnetic moments are far more disruptive to MRI than a spatially uniform paramagnetic contribution from conduction electrons. Ferromagnetic substances are strongly attracted to magnetic fields and therefore have a high potential to cause MRI artefacts (e.g., iron, cobalt, nickel). The overall magnetic behaviour of dental alloys depends on their composition, and the presence of a magnetic element does not necessarily determine the magnetic properties of the final alloy.[1]

The purpose of this study was to evaluate and compare the magnetic properties of precious- and base-metal dental alloys in an external magnetic field and to assess their potential implications for MRI safety and Image quality.

2 EXPERIMENTAL PART

Precious dental alloys 1–4 were produced in an established manufacturing process for precious dental alloys, while base-metal dental alloys 1–3 were obtained as commercially available materials for dental technicians.

2.1 Production of precious alloys 1–4

Four precious alloys were prepared from high-purity raw metals (≥99.9 %) according to the predefined compositions. The required amounts of gold, platinum, palladium, silver and other metals were weighed using an analytical balance with an accuracy of ±0.01 g. The components were melted in a melting furnace under an inert argon atmosphere to prevent oxidation and contamination. Melting was performed in graphite crucibles at temperatures appropriate for each alloy system (typically 1100–1500 °C), ensuring complete homogenization of the melt.

The cast ingots were subsequently rolled with intermittent annealing into strips with a uniform thickness of 1.4 mm. The rolled strips were then cut into standardized metal casting tiles of (7 x 7) mm, suitable for dental laboratory processing, and stamped with the alloys' trade names for casting tile identification. Prior to further use, the tiles were cleaned to remove surface contaminants and stored under dry conditions.

A single precious alloy was prepared from each set of high-purity raw metals (≥99.9 %) according to the predefined compositions and cast using a Galloni G3 casting machine with a water-container setup for casting into granules. The precious dental alloy casting compositions in *w*/% were as follows:

- Precious alloy 1 (PA1): AuPdAgCuZn alloy, in tile form, with a composition of Au 2.0 %; Pd 25.0 %; Ag 64.0 %; Cu 8.0 %; Zn < 1 %
- Precious alloy 2 (PA2): AuPtAgGeIrRh alloy, in tile form, with a composition of Au 80.0 %; Pt 10.84 %; Ag 8.0 %; Ge 1.0 %; Ir, Rh < 1 %
- Precious alloy 3 (PA3): PdAgZnSnInIr alloy, in granule form, with a composition of Pd 56.2 %; Ag 35.0 %; Zn 4.5 %; Sn 2.0 %; In 2.0 %; Ir < 1 %
- Precious alloy 4 (PA4): AuPdAgCuZnIr alloy, in tile form, with a composition of Au 46.0 %; Pd 6.0 %; Ag 39.5 %; Cu 7.5 %; Zn, Ir < 1 %

The composition of each batch of the produced alloy was verified with X-ray fluorescence (XRF) analysis using a Niton XL3t GOLDD+ analyzer (Thermo Fisher Scientific, Waltham, Massachusetts, USA), with corresponding metal alloy standards.

2.2 Base-metal dental alloys 1–3

The base-metal alloys were purchased in the prefabricated casting form from certified dental material manufacturers Interdent d.o.o., Celje, Slovenia, and BEGO GmbH & Co., Bremen, Germany. The selected alloys included:

- Base alloy 1 (BA1): CoCrWMoSi alloy, in cast cylindrical form, with a composition of Co 63.0 %; Cr 24.0 %; W 8.0 %; Mo 3.0 %; Si 1.0 %; Nb < 1 % (Interdent)
- Base alloy 2 (BA2): CoCrMoSi alloy, in cast cylindrical form, with a composition of Co 63.5 %; Cr 29.1 %; Mo 5.0 %; Si 1.3 %; Mn, C, N < 1 % (Interdent)
- Base alloy 3 (BA3): CoCrMoMnSi alloy, in cast cylinder form, with a composition of Co 62.5 %; Cr 29.5 %; Mo 5.0 %; Mn 1.5 %; Si 1.0 %; C, N, Ta < 1 % (Bego)

All purchased materials were supplied with manufacturer certificates specifying chemical composition and batch numbers.

3 RESULTS AND DISCUSSION

3.1 Magnetic properties

Magnetization, M, and magnetic susceptibility, $\chi = M/H$, of the investigated dental alloys were determined using a Quantum Design MPMS3 magnetometer, equipped with a 7 T magnet.

The samples were prepared for magnetic measurements by cutting them with a wire saw into cuboids with approximate dimensions of (1.5 × 1.5 × 3.0) mm. The cuboids were then placed into plastic straws, which are commonly used as sample holders for magnetic measurements in MPMS3 magnetometers.

The result of a single measurement at particular magnetic field strength, H (SI unit A/m), and temperature, T, is a magnetic moment, p_m, of the investigated sample, expressed in Am^2. The experimental data in **Figure 1a** are presented as volume magnetization, $M = p_m/V$, where V is the volume of the sample. The volume magnetic susceptibility, χ (dimensionless, unit 1), shown in **Figure 1b**, was obtained from the ratio $\chi = M/H$, measured at a constant magnetic field strength of H = 79.575 A/m, corresponding in vacuum to a magnetic flux density of $B = \mu_0 H$ = 0.1 T.

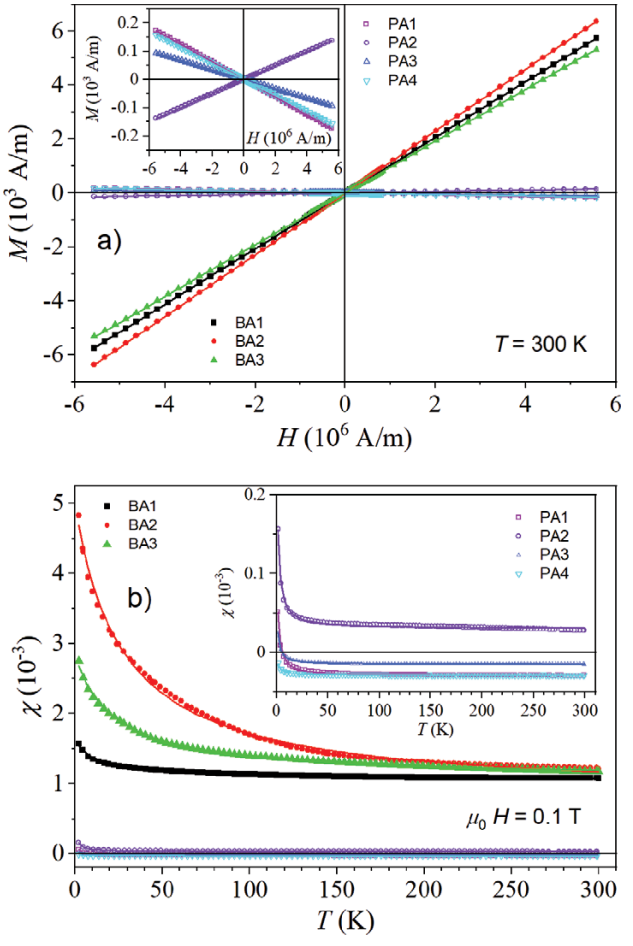

Figure 1: a) Magnetisation, M, as a function of magnetic field strength, H, at 300 K (27 °C) and b) temperature dependent susceptibility, χ, measured in a magnetic field of 0.1 T

Magnetization curves $M(H)$, measured at a temperature of 300 K (27 °C), are presented in **Figure 1a**. For all investigated dental alloys, the $M(H)$ dependence is linear. The linear fits of $M(H)$ at 300 K are shown as solid lines. The measured slopes – and thus the magnetic susceptibilities $\chi = M/H$ at 300 K – differ greatly. The three base-metal dental alloys exhibit large positive susceptibilities on the order of $\chi \approx 10^{-3}$ (**Table 2**), whereas the susceptibilities of the four precious alloys are two orders of magnitude smaller in absolute value. For three of them – PA1, PA3, and PA4 – the susceptibilities are even negative, indicating diamagnetic behaviour. None of the alloys show any indication of ferromagnetism.

To clarify the origin of the relatively large paramagnetic susceptibility observed at 300 K and to distinguish the contribution of localized magnetic moments from the paramagnetism of conduction electrons, we measured the temperature-dependent susceptibility in a magnetic field of 0.1 T – see **Figure 1b**. The contribution of conduction electrons is, to first approximation, temperature independent,[13] whereas the susceptibility of localized magnetic ions increases upon cooling according to $C/(T-\theta)$. Here, C is the Curie constant, proportional to the concentration of localized magnetic moments, and θ is the Curie–Weiss temperature. In principle, the Curie–Weiss temperature reflects the strength of magnetic interactions between the localized moments. For the dental alloys investigated in this work, such interactions are not expected (implying $\theta = 0$), but we kept θ as a free fitting parameter to achieve a better agreement between the measured data and the fit.

The temperature dependences of the susceptibility shown in **Figure 1b** were thus fitted using the expression:

$$\chi = \chi_0 + C/(T-\theta).$$

The resulting fits are plotted as solid lines in **Figure 1b**, and the extracted Curie constants are listed in **Table 2**. Among the investigated dental alloys, PA3 and PA4 exhibit the most favourable magnetic behaviour. They have the smallest absolute susceptibility at 300 K ($\approx -2 \times 10^{-5}$) and, at the same time, very low Curie constant C (below 10^{-4}). The latter indicates that PA3 and PA4 contain the least amount of possible magnetic impurities.

To compare the contributions of localized magnetic moments and conduction electrons to the magnetic susceptibility at 300 K, we analysed the Curie–Weiss term, $C/(T-\theta)$, and the Pauli paramagnetic contribution, χ_{Pauli}, respectively. We first estimated χ_{Pauli} for two representative alloys: PA2 from the precious-metal alloy series and BA2 from the base-metal alloy series, using temperature-dependent susceptibility measurements.

The temperature-independent susceptibility term, χ_0, consists of the diamagnetic contribution of the core electrons, χ_{dia}, which can be obtained from the literature,[14] and the paramagnetic contribution of the conduction

electrons, χ_{Pauli}. Accordingly, χ_{Pauli} was determined as $\chi_{Pauli} = \chi_0 - \chi_{dia}$.

For PA2, we obtained $\chi_{Pauli} = 6.3 \times 10^{-5}$, whereas for BA2 $\chi_{Pauli} = 1.2 \times 10^{-3}$. In contrast, the contributions of localized magnetic moments to the susceptibility at 300 K are 0.1×10^{-5} for PA2 and 0.35×10^{-3} for BA2. Consequently, the contribution of localized magnetic moments to the total susceptibility at 300 K is below 2 % for PA2, while it amounts to approximately 30 % for BA2.

The significantly larger contribution of localized magnetic moments in the base-metal alloys is consistent with their chemical composition, which includes elements such as Co, Cr, and Mo that are ferromagnetic or paramagnetic in their elemental form. Importantly, our experimental results – specifically the linear $M(H)$ response at 300 K – provide no evidence for the presence of ferromagnetic impurities in the investigated alloys.

Table 2: Magnetic susceptibility, χ, at 300 K obtained from the $M(H)$ dependences at 300 K, and Curie constant, C, obtained from the temperature dependent susceptibility, $\chi(T)$, of the seven dental alloys

Dental alloy	χ from $M(H)$ at 300 K	C (K)
PA1	$-3.12 \cdot 10^{-5}$	$0.19 \cdot 10^{-3}$
PA2	$2.48 \cdot 10^{-5}$	$0.30 \cdot 10^{-3}$
PA3	$-1.66 \cdot 10^{-5}$	$0.09 \cdot 10^{-3}$
PA4	$-2.82 \cdot 10^{-5}$	$0.05 \cdot 10^{-3}$
BA1	$1.03 \cdot 10^{-3}$	$7.6 \cdot 10^{-3}$
BA2	$1.14 \cdot 10^{-3}$	$113 \cdot 10^{-3}$
BA3	$0.96 \cdot 10^{-3}$	$39 \cdot 10^{-3}$

4 CONCLUSIONS

Based on the research conducted, we can draw the following important conclusions:

1) For all investigated dental alloys, the $M(H)$ dependence is linear. The three base-metal dental alloys exhibit large positive susceptibilities on the order of $\approx 10^{-3}$, whereas the susceptibilities of the four precious alloys are two orders of magnitude smaller in absolute value. The positive magnetic susceptibility of the base-metal dental alloys arises from the combined contribution of the paramagnetism of conduction electrons and the paramagnetism associated with localized magnetic moments.

2) For precious alloys PA1, PA3, and PA4, the susceptibilities are even negative, indicating diamagnetic behaviour.

3) Among the investigated dental alloys, PA3 and PA4 exhibit the most favourable magnetic behaviour. Both show diamagnetic susceptibilities on the order of -10^{-5}, which is close to the magnetic susceptibility of water and, consequently, to that of the human body, whose magnetic response is very similar to that of water. In the context of MRI, this implies minimal disturbance of the magnetic field in the vicinity of the dental alloy, rendering these materials essentially magnetically invisible within the surrounding human tissue and resulting in the smallest possible impact on the acquired magnetic resonance images.

At the same time, these two precious alloys exhibit the lowest Curie constants, 0.09×10^{-3} and 0.05×10^{-3} for PA3 and PA4, respectively, indicating the lowest concentration of localized magnetic moments and, therefore, the smallest amount of possible magnetic impurities among all investigated dental alloys.

Acknowledgment

This work was partially financially supported by the Slovenian Research Agency (Grant No. P2-0348 and P1-0125).

6 REFERENCES

[1] H. Hubálková, P. La Serna, I. Linetskiy, T. Dostálová, Dental Alloys and Magnetic Resonance Imaging, Int. Dent. J., 56 (**2006**), 135–141, doi:10.1111/j.1875-595X.2006.tb00085.x

[2] F. Shafiei, E. Honda, H. Takahashi, T. Sasaki, Artifacts from Dental Casting Alloys in Magnetic Resonance Imaging, J. Dent. Res., 82 (**2003**), 602–606, doi:10.1177/154405910308200806

[3] B. J. Wilson, P. E. O'hare, J. Zacariah, Implications and Considerations of Dental Materials in MRI: A Case Report and Literature Review, Case Rep. Dent., (**2020**), 8891302, doi:10.1155/2020/8891302

[4] M. Öçbe, The Evolving Role of MRI in Dentomaxillofacial Diagnostics: A Comprehensive Review, Eur. Oral Res., 59 (**2024**), 58–67, doi:10.26650/eor.2024145664

[5] J. D. M. de Matos, A. C. M. dos-Santos, L. J. N. Nakano, J. E. L. de-Vasconcelos, V. C. Andrade, R. S. Nishioka, M. A. Bottino, G. da R. S. Lopes, Metal Alloys in Dentistry: An Outdated Material or Required for Oral Rehabilitation?, International Journal of Odontostomatology, 15 (**2021**), 702–711, doi:10.4067/S0718-381X2021000300702

[6] Y.-H Chang, Y.-T. Pan, C.-Y. Chao, H.-E. Lee, J.-H. Wu, Corrosion Behavior of Dental Alloys Under Artificial Saliva Solution with Different PH Values, The Journal of Dentists, 10 (**2022**), 1–6, doi:10.12974/2311-8695.2022.10.1

[7] R. Rudolf, V. Lazić, P. Majerič, A. Ivanič, G. Kravanja, K. T. Raić, Dental Gold Alloys and Gold Nanoparticles for Biomedical Applications, SpringerBriefs in Materials, Springer International Publishing, Cham 2022, ISBN 978-3-030-98745-9

[8] A. Vaicelyte, C. Janssen, M. Le Borgne, B. Grosgogeat, Cobalt–Chromium Dental Alloys: Metal Exposures, Toxicological Risks, CMR Classification, and EU Regulatory Framework, Crystals, 10 (**2020**), 1151, doi:10.3390/CRYST10121151

[9] B. Grosgogeat, A. Vaicelyte, R. Gauthier, C. Janssen, M. Le Borgne, Toxicological Risks of the Cobalt–Chromium Alloys in Dentistry: A Systematic Review, Materials, 15 (**2022**), 5801, doi:10.3390/ma15175801

[10] J. C. Wataha, Biocompatibility of Dental Casting Alloys: A Review, J. Prosthet. Dent., 83 (**2000**), 223–234, doi:10.1016/S0022-3913(00)80016-5

[11] S. J. Chockattu, D. B. Suryakant, S. Thakur, Unwanted Effects Due to Interactions between Dental Materials and Magnetic Resonance Imaging: A Review of the Literature, Restor. Dent. Endod., 43 (**2018**), doi:10.5395/rde.2018.43.e39

[12] D. Sinkiewicz, MRI Scan Hazard, Br. Dent. J., 214 (2013), 376–376, doi:10.1038/sj.bdj.2013.388

[13] N. W. Ashcroft, N. D. Mermin, Solid State Physics, Saunders College Publishing, Fort Worth 1976

[14] G. A. Bain, J. F. Berry, Diamagnetic Corrections and Pascal's Constants, J. Chem. Educ., 85 (**2008**), 532, doi:10.1021/ed085p532