Stomatologija. Baltic Dental and Maxillofacial Journal, 26: 30-6, 2024

Influence of surface treatment on the survival rate of miniscrews: A systematic literature review and meta-analysis

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SUMMARY

Background. Dental or skeletal anchoring plays a significant role in the orthodontic treatment of various malocclusions. Miniscrews are now regarded as stable skeletal anchoring. Despite their popularity, miniscrew success rates in studies range from 83.9 to 93.3%. Surface treatment is one of its properties that is now being extensively researched and enhanced. Consequently, the purpose of this systematic review is to ascertain how miniscrew surface treatment affects insertion torque, success rate, and removal torque.

Materials and methods. The protocol for conducting a systematic literature review followed the PRISMA criteria. The keywords "mini-implant", "mini-screw", "orthodontic mini screws", "survival rate", and "surface treatment" were used to search electronic databases. This systematic review included human studies published in English within the previous five years that compared the success rates of miniscrews with and without changed surfaces.

Results. Four included studies assessed the effect of surface modification on the success rate; two of them examined the impact on insertion torque, one the removal torque, and one assesed the periotest value. The rough surface group achieved a higher success rate than the non-modified group, although the difference was not statistically significant. The treated surface group had higher removal torque than the non-treated group, but the difference was not statistically significant.

Conclusions. Quantitative and qualitative analysis revealed that surface-treated miniscrews had a greater success rate and insertion torque than non-treated ones, although the difference was not statistically significant.

Keywords: mini-implant, mini-screw, orthodontic mini screws, survival rate, surface treatment.

INTRODUCTION

Orthodontic tooth movement control is important during various malocclusion treatment (1). It is usually achieved by using dental or skeletal anchorage. In some cases, conventional appliances cannot provide stable support (2). Forces, created by rapid maxillary expanders, can cause undesirable dental movement, palatal arches develop weaker force and extraoral appliances, such as orthodontic headgears and face masks are undesirable due to discomfort, unesthetic appearance and the need of patient cooperation (1, 3-6).

Modern skeletal anchoring components, such as titanium miniscrews, have been introduced to mitigate the negative effects of the previously stated devices. These elements are distinguished by minimal invasiveness, simple adaption, and removal (7). The miniscrews' small size makes them easier to apply in constrained anatomical spaces (between the roots of adjacent teeth) and cause less discomfort for the patient (1-4, 8). In addition, the effectiveness of treatment does not fully depend on patient's motivation, which frequently results in treatment failure (9).

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Despite the popularity of miniscrews, their survival rate varies widely in different studies (83.9-93.3%) (10). Miniscrew surface treatment as a way to improve miniscrew stability is one of the aspects being widely researched. The titanium surface can be roughened by using chemical, mechanical or combined methods. Sandblasting and acid etching of the miniscrew surface are the most widely studied for their positive properties. It is expected that surface treatment can increase the success of miniscrews by improving osseointegration and healing (11). For chemical preparation, combinations of acids (for example, hydrofluoric and nitric acid) can be used, which can form 0.2-2 μm cavities on the surface of the mini-screw, and for mechanical treatment, 20-40 ηm nanoparticles can be used, forming a surface with high hydrophilicity (12). Surface treated miniscrews are called SLA (sandblasted, large grit, acid-etched), which, unlike miniscrews with an untreated surface, are characterized by biological stability due to the osseointegration.

Al-Thomali *et al.* conducted a systematic review and meta-analysis of animal studies and compared the dependence of the properties of miniscrews on their surface treatment. The study concluded that surface treatment of miniscrews has a statistically significantly positive influence on the primary and secondary stability of the screw and its retention in the bone tissue (13). Human studies of this type have lately appeared in online databases, thus the purpose of this article is to review these studies and establish whether surface treatment of the miniscrew influences its survival rate, insertion and removal torque.

MATERIAL AND METHODS

Methods

A systematic literature search was conducted according to PRISMA guidelines (14). The focused question was developed according to PICOS model, based on the population, intervention, control, and outcome:

- Population (P) – patients who have undergone the insertion of miniscrews;
- Intervention (I) – surface treated miniscrews;
- Control (C) – untreated miniscrews;
- Outcome (O) – mechanical stability of miniscrews.
- Does the surface treatment of a miniscrew affect its survival rate?

Search strategy

The search was carried out by all authors using the electronic databases Pubmed, Science Direct, The Willey Online Library, LILACS, Google Scholar. The keywords "Mini-implant", "Mini-screw", "Orthodontic mini screw", "Survival rate", "Surface treatment" and their combinations were used for the search. Later, the literature sources of scientific articles identified by keywords were analyzed to find additional scientific articles that met the criteria.

Eligibility criteria

Studies, included in the systematic review were published in English language, not older than 5 years, in which stability and survival rate of miniscrews with treated surface and untreated surface was compared. Animal studies, in vitro studies, case reports, systematic reviews, meta-analyses were excluded from the search.

Study selection and data collection process

Electronic search was conducted and studies that seemed to have an eligible title and abstracts were selected. Full-text documents of selected studies were then analysed and the ones that did not match the inclusion criteria were discarded.

Methodological quality

The risk of bias was evaluated using ROB2 tool for randomised controlled trials (15). The tool was used to assess the randomisation process, deviations from the intended interventions, missing data, measurement of the outcomes and selection of the reported results. ROBINS-1 tool for retrospective cohort studies was used to determine research errors such as patient selection, classification of interventions, deviation from the intended intervention, missing outcome data, measurement of the results, selection of published results (16).

Statistical analysis

The summarized statistical analysis of the selected articles was carried out using Review Manager (RevMan) 5.4.1 computer program developed by Cochrane. The heterogeneity of the selected studies was assessed using the Higgins I2 and Cochrane Q tests. The heterogeneity of the studies resulting from the fluctuation of the intervention effect between studies was interpreted according to the Higgins I2 test: 0-40% heterogeneity is irrelevant, 30-60% heterogeneity is moderate, 50-90% heterogeneity is strong, 75-100% heterogeneity is significant.

The Cochrane Q test determined the statistical significance of heterogeneity - at $p<0.05$, the difference in the intervention effect between the studies was considered statistically significant (16, 17). In the meta-analysis, the magnitude of the effect was estimated by calculating odds ratio, mean difference and confidence intervals of 95%. The effect measure is calculated using a random effects model, which summarizes the results of the study using an inverse variance method.

One meta-analysis was performed to assess whether the survival rate of miniscrews differed statistically significantly between the treated and untreated surface miniscrew groups. Another meta-analysis was performed to compare the difference in the insertion torque between the miniscrew groups of the treated and the untreated surface.

RESULTS

Study selection

Primary database search yielded 1995 scientific articles. After removal of duplicates, 1352 articles remained. Titles and abstracts of those studies were screened and 11 articles were selected for the full text analysis. After applying inclusion criteria, 4 studies were selected for qualitative and quantitative analysis (18, 19, 20, 21). A detailed search for scientific articles suitable for analysis is shown in the PRISMA Flow diagram (Figure 1).

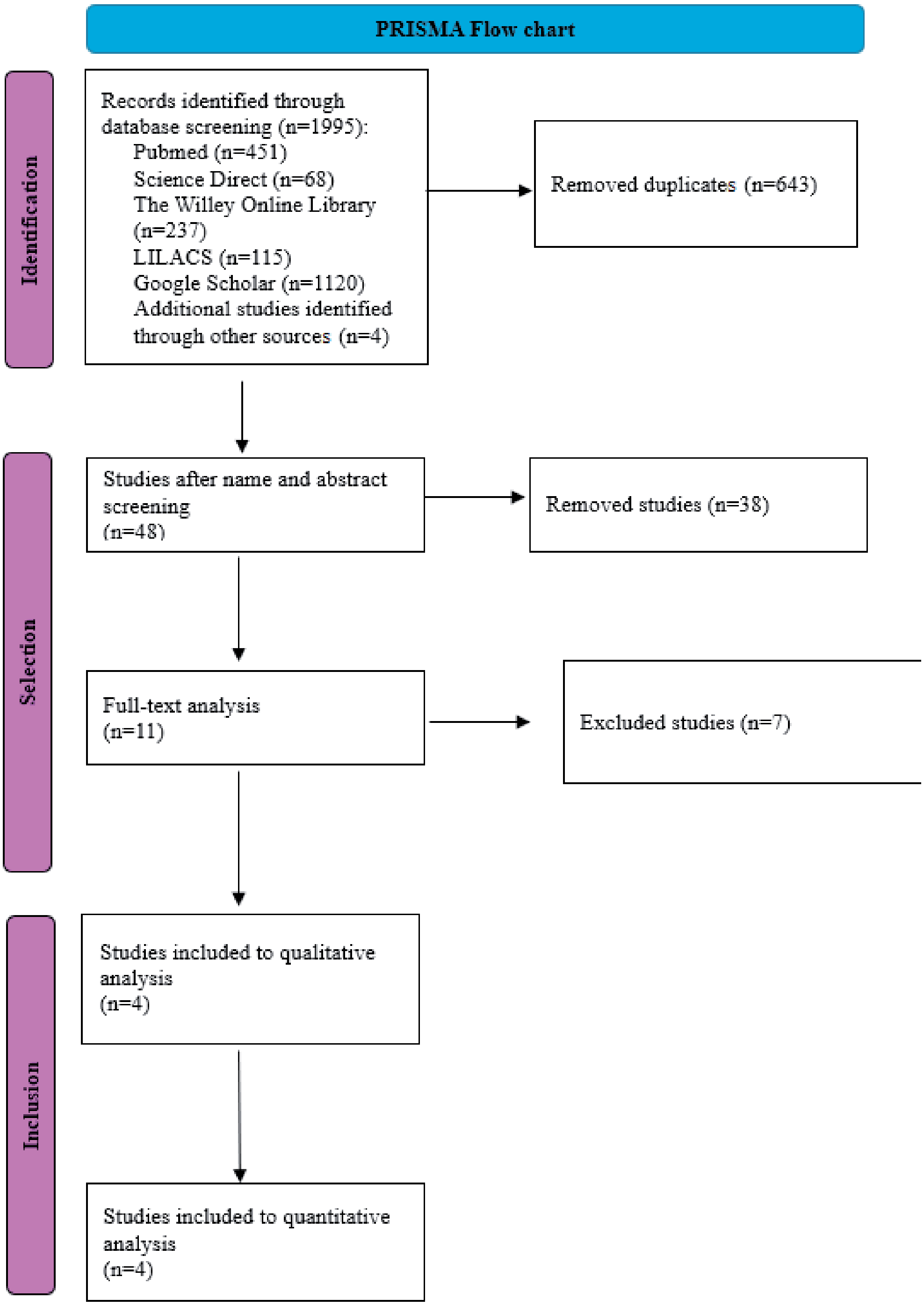

Fig. 1. PRISMA flow chart

Characteristics of included studies

The systematic review included four studies in humans, three of which were randomized controlled trials (18-20) and one was a prospective clinical study (21). A total of 120 patients participated in the studies and 270 miniscrews were examined. Patient samples ranged from 10 to 40, with an average of 30 patients included in each study.

The selected studies investigated the influence of the surface treatment of miniscrews on mechanical stability and survival. Miniscrews were divided into control (untreated surface) and test (treated surface) groups. Two studies compared the control group with SLA miniscrews (19, 21), the other two with acid-treated only (18, 20). All studies indicated the success rate of both groups (18-21), two scientific papers measured the insertion torque (18, 19), one measured removal torque (19), one – primary stability (18), using the value of "periotest". In two scientific articles, all the minicrews used were of the same di-

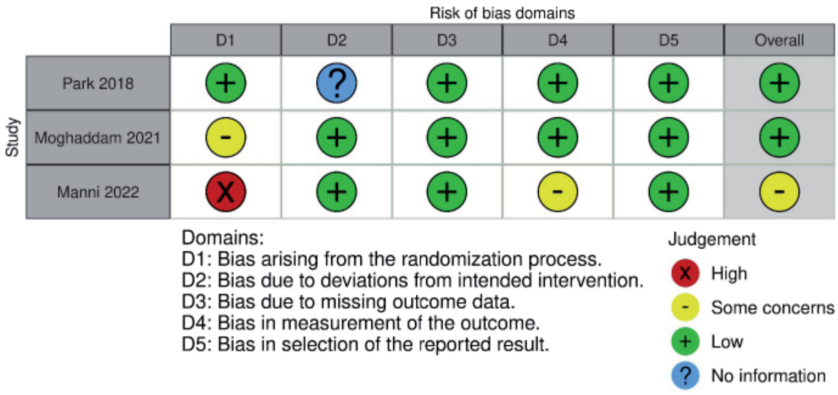

Fig. 2. Risk of bias evaluated using ROB2 tool

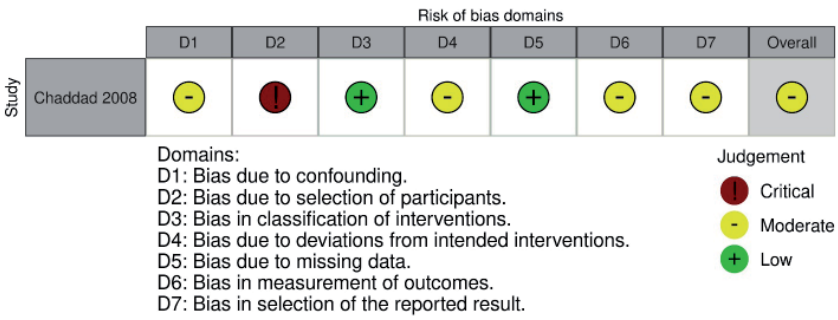

Fig. 3. Risk of bias evaluated using Robins 1 tool

mensions (18, 19), in the other two, the dimensions between the miniscrews differed (20, 21). The authors of three articles used self-drilling screws (18-20) and one used self-tapping screws (21). In three scientific articles, miniscrews were inserted into both jaws (18, 19, 21), in one only into the mandible (20). All studies indicate the exact anatomical location of the insertion (18-21). In all scientific studies, miniscrews were loaded (18-21). In two studies, the load was carried out immediately after the insertion (20, 21), in one – 4 weeks after insertion (18), in one – after 6 weeks (19). The detailed characteristics of the studies are given in the Table.

Risk of bias of the included studies

The risk assessment of systemic errors in the studies included in the systematic review was carried out using RoB2 and ROBINS-1 standardized tools (16, 17). The RoB2 tool assessed the risk of systemic errors in the included studies using 5 standardized criteria, ROBINS-1 – 7 criteria. Two of the included randomized studies (18, 19) had a low risk of systemic error, one study (20) had a moderate risk. A detailed assessment of the risk of systemic errors in these studies is presented in Figure 2. One case control study (21) had an average risk of systemic error and its detailed assessment is given in Figure 3.

Qualitative synthesis of results

All the studies included in the systematic review studied the dependence of the survival rate of miniscrews on surface treatment. Three of the four studies claimed that the survival rate of miniscrews in the study group is higher than in the control group, but this difference was not statistically significant (p>0.05) (18, 19, 21). In the Moghaddam *et al.* study, the success of miniscrews was 90.3% in the study group, while in the control group it was 83.9%, but the difference was not statistically significant (p=0.44) (19). Park *et al.* found that the success of miniscrews on the treated surface was 91.8%, while in the control group it was 85.7%, but this difference was not statistically significant either (p=0.323) (18). In the study of Chaddad *et al.*, the number of successful miniscrews in the study group was also higher than in the control group, but not statistically significant (p=0.348), and the success rates were 93.4% and 82.4% respectively (21). Meanwhile, in the study performed by Manni *et al.*, the number of successful miniscrews in the study group was lower than in the control group – 71.8% and 74.4%, respec-

Table. General characteristics of the selected studies

Author (year)	Miniscrew survival rate		Insertion torque (Ncm)		Removal torque (Ncm)		PTV	
	TG	CG	TG	CG	TG	CG	TG	CG
Chaddad et al. (2008)	93.4% (14/15)	82.4% (14/17)	-	-	-	-	-	-
Parket et al. (2018)	91.8% (45/49)	85.7% (42/49)	13.62±5.95	13.38±4.0	-	-	-0.50±2.77	-0.28±3.36
Moghaddam et al. (2021)	90.3% (28/31)	83.9% (26/31)	12.10±6.295	12.42±5.755	10-30 (15.71±5.563)	5-10 (8.08=2.481)	-	-
Manni et al. (2022)	71.8% (28/39)	74.4% (29/39)	-	-	-	-	-	-

TG, test group (treated surface); CG, control group (untreated machined surface).

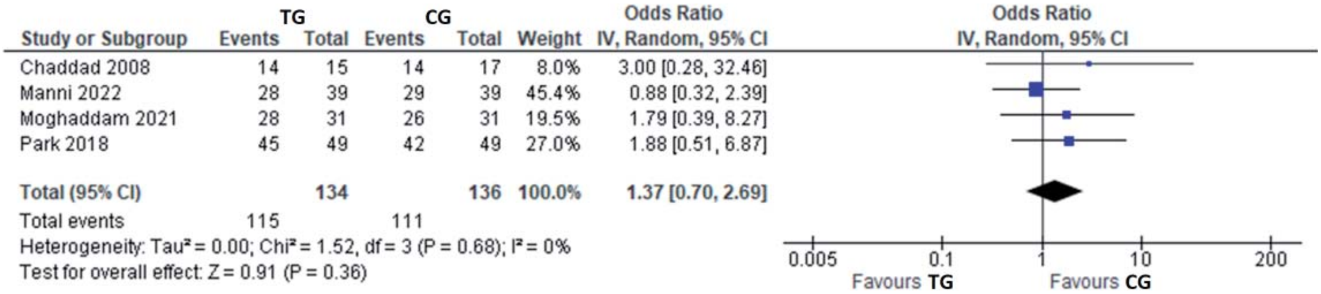

Fig. 4. Forest Plot used to compare miniscrew survival rate between surface treated and untreated miniscrew groups

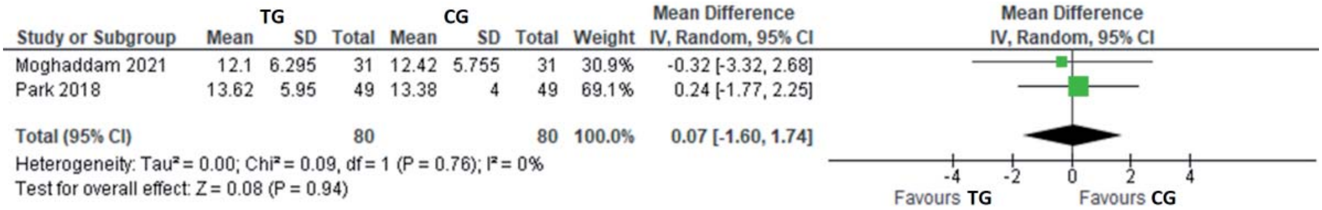

Fig. 5. Forest Plot used to compare miniscrew insertion torque between surface treated and untreated miniscrew groups

tively, but the difference between the two groups was statistically insignificant (p=0.6147) (20).

Two articles evaluated the insertion torque. One study found that insertion torque of the miniscrews of the untreated surface was higher than the control group (12.42±5.755 Ncm and 12.10±6.295 Ncm respectively), however the difference was not statistically significant (p=0.83) (19). Another study showed that insertion torque in the study group was higher than in the control group (13.62±5.95 ir 13.38±4.0 respectively). The difference was not statistically significant (p=0.818) (18).

Moghaddam *et al.* evaluated the removal torque of the miniscrews. The removal torque was statistically signIficantly higher in the study group than in the control group (15.71±5.563 Ncm and 8.08±2.481 Ncm respectively) (19).

The stability of the miniscrews was evaluated by Park *et al.*, and it was measured using "Periotest value" (PTV). Primary stability was evaluated in two stages: immediately after the insertion of the miniscrew and 6 months after the insertion. The difference between study and control groups was not statistically significantly different during both times of measuring (18).

Quantitative synthesis of results

The results of meta-analysis showed that the survival rate of surface treated miniscrews was higher than control group, however the difference was not statistically significant (OR=1,37, 95 % Cl=0,70, 2,69; p=0,36), heterogeneity was non-existant (I2=0 %, P=0,68). The results are displayed in Forest plot diagram (Figure 4).

Meta-analysis was performed to compare the difference of insertion torque between study and control groups. The results showed that insertion torque in the study group was slightly higher than control group, however the difference was not significant (OR=0,07, 95 % Cl=-1,60, 1,74; p=0,94), heterogeneity was non-existant (I2=0 %, P=0,76). The results are displayed in the Forest plot diagram (Figure 5).

DISCUSSION

This systematic review analyzed four studies, which compared the surface treated and untreated miniscrews. All articles were included in the quantitative and qualitative analysis. Three out of four studies showed higher survival rates of miniscrews with treated surface, but the results were not statistically significant. The meta-analysis confirmed those results.

The primary stability of miniscrews, which determines miniscrew success, is characterized by measuring the insertion torque or the periotest value immediately after insertion (12). Two studies (18, 19) examined differences in insertion torque between treated and untreated surface groups. In a qualitative data analysis, it was found that the insertion torque was higher in the control group in one study (19) and in the experimental group in another study (18). In both studies, the difference between the insertion torque of miniscrews was not statistically significant, which was also confirmed by the data of the meta-analysis. Although no differences in insertion torque were found between the two groups in this systematic review, Al-Thomali *et al.*

a systematic review of studies with animals states that higher insertion torque is obtained in groups of smooth surface miniscrews (13). It was believed that the ideal miniscrew insertion torque in alveolar processes is 5-15 Ncm (13). Excessive force causes the formation of stress and necrosis zones in the bone tissue, which can become the reason for the failure of miniscrews (8, 22). Meanwhile, the treated surface allows mini-screws to be inserted with the minimum required force, since the roughening of the surface creates an additional area of the mini-screw in contact with blood and osteogenic cells (13). In this way, cell migration takes place towards the surface of the miniscrew, where fibrin is attached and secondary stability increases (11). However, a study of maximal miniscrew insertion forces found no significant associations with miniscrew success (23). Differences in the insertion torque between treated and untreated surface groups should be interpreted with caution, because the insertion torque also depends on the type of mini-screw type (self-drilling or self-tapping), parameters, and cortical bone thickness (22, 24).

The secondary stability of the miniscrew is measured by the removal torque (12, 13). Removal torque was investigated in one study, where it was found that it was statistically significantly higher in the study group compared to the control (19). The increased removal torque in the rough surface mini-screw group indicates that more efficient osseointegration occurred between the bone and the miniscrew. The treated surface of miniscrews activates cell proliferation, differentiation, and migration in its contact with bone (13). Bone apposition is further promoted by the hydrophilicity and biocompatibility of the treated surface (25). With the formation of close contact, the retention and friction coefficient increases, so mini-screws require a higher unscrewing force (4, 12). Surface roughening has a positive effect not only on secondary stability, but also on healing (11, 12, 13). The rough surface, in contrast to the smooth, prevents the separation of the fibrin from the surface of the miniscrew. Fibrin helps osteogenic cells to migrate and form bone on the surface of the miniscrew (11). When studying miniscrews with a treated surface, the change in the unthreading force is presented as a favorable criterion in many sources (11, 12). On the other hand, Park *et al.* study evaluated miniscrew PTV 6 months after insertion, when osseointegration is expected to have occurred, but there was no statistically significant difference between groups (18). Although meta-analysis could not be performed to compare the differences in removal torque between treated and untreated surface miniscrews because the removal torque was measured in only one study, there is sufficient evidence in the literature that treated surface miniscrews have higher removal torque, secondary stability, and can be safely removed at the end of treatment even after osseointegration (6, 9, 13, 19, 26).

The systematic review had some limitations. Firstly, the number of included studies in this systematic review and meta-analysis is the main limitation. There were some factors in the included studies that had significant effect on miniscrew survival rates, therefore more homogenic articles should be published for better evaluation.

CONCLUSIONS

Within the limitations of the included articles, it can be concluded that the surface treatment of miniscrews does not have statistically significant difference on their survival rate and stability.

CONFLICT OF INTEREST

None.

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Received: 09 05 2023
Accepted for publishing: 21 06 2024