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The risk of tooth root injuries using cortical screws for intermaxillary fixation and osteosynthesis plates – A retrospective analysis

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ABSTRACT

Intermaxillary fixation (IMF) and osteosynthesis plates (OP) are widely used for the non-surgical and surgical treatment of mandible and condyle fractures. The aim of this retrospective study was to analyze the frequency of tooth root injuries by IMF and OP screws.

Electronic patient reports (2004–2013) were screened for patients treated with either IMF screws and/or OP in the Department of Oral- and Maxillofacial Surgery, University Medical Center Mainz, Germany. The frequency and the position of endangered and injured teeth were analyzed by orthopantomogram (OPTG) and cone beam computer tomography (CBCT). Next, possible predictive factors for tooth root injuries, namely interdental- and crestal distance, screw length and distance between tooth root and screw were evaluated. Further, the accuracy of OPTG vs. CBCT concerning the diagnosis of tooth root injuries was analyzed. Three-hundred sixty-six patients were included and 3388 teeth were defined as endangered by IMF- and OP screws. Overall, 16 injured teeth (0.5%) in 13 patients (3.55%) were detected. Nine injuries (56.3%) were caused by IMF- and seven injuries (43.8%) by OP screws. Three teeth were non-vital, one tooth had to be extracted. No correlation between the predictive factors crestal distance, screw length and tooth root injuries was found. If tooth injury occurred, a significant correlation between the interdental distance and the distance between tooth root and screw was found ($\kappa = 0.48$; $p < 0{,}0001$). Comparison between OPTG vs. CBCT demonstrated that many of the injuries that were seen in the OPTG ($n = 230$) could not be verified in the CBCT scans ($n = 16$) ($\kappa = 0.12$).

To conclude, screws for IMF and OP can be considered as a safe procedure concerning the risk of tooth root injuries.

1. Introduction

For a long time, splints and arch bars for intermaxillary fixation (IMF) represented the usual treatment of mandible and condyle fractures. In the next step, osteosynthesis plates (OP) with matching screws were developed by Champy and the Association for the Study of Internal Fixation (AO) on the principles of tension band plating (Champy et al., 1978). In many cases, OP represents the "state-of-the-art" treatment for fractures of the midface, the mandible, condyles or other kinds of cranio-maxillofacial bone repositioning, such as in orthognathic surgery (Sauerbier et al., 2008). Recent developments enable the three-dimensional planning and production of patient individual OP of high-performance titanium alloys or resorbable composites (Probst et al., 2016; Voss et al., 2016; Leno et al., 2017). The object of both procedures –

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IMF and OP – is to ensure sufficient bone healing, regular mandible mobility and function and the restoration of the dental occlusion (Anslem et al., 2017).

Despite the increasing popularity of OP, the principle of IMF further represents an important treatment option, alone or in combination with OP. To overcome the disadvantages and limitations of splints and arch bars for IMF, Arthur and Berardo developed the first (non self-drilling) IMF screws (Arthur and Berardo, 1989). In the next step, self-drilling IMF screws were developed, representing the current standard (Roccia et al., 2009). Compared to splints and arch bars (e.g., Schuchardt splint), self-drilling IMF screws enable a simple and fast insertion and IMF with wire- or elastic loops. The main advantages are: reduced irritation of the oral mucosa, no tooth movements, a reduced risk of stab injuries for the surgeon, and further, reduced social isolation, improved diet possibility, clearly better oral hygiene, and overall a higher rate of acceptance, satisfaction and quality of life for the patient (Coletti et al., 2007; van den Bergh et al., 2015a; van den Bergh et al., 2015b). With respect to patients' comfort comparing OP vs. IMF, IMF is associated with disadvantages such as mouth closing, liquid diet and decreased oral hygiene (Carricondo et al., 2017). Contrarily, Omeje et al. (2014) compared OP vs. IMF in condyle fractures regarding the quality of life and reported no differences. The IMF group was more influenced by a psychological domain, while the internal fixation group was influenced by pain (Omeje et al., 2014).

Screws for IMF can sufficiently be used for (I) the temporary immobilization of fractures, (II) the intraoperative reposition and stabilization of bone fragments, (III) the postoperative stabilization and occlusion protection as well as the (IV) the non-surgical treatment of mandible or condyle fractures (Arthur and Berardo, 1989; Burnham et al., 2011; Theologie-Lygidakis et al., 2016; Batbayar et al., 2017). With respect to the functional outcome comparing OP vs. IMF, Anslem et al. demonstrated comparable functional results in the treatment of simple unilateral mandible fractures by IMF vs. 2 mm non-compression miniplates (Anslem et al., 2017).

A possible complication of both IMF and OP is the appearance of tooth root injuries by screws. For IMF screws, tooth root injury was reported to be the most relevant side effect (Nandini et al., 2011). Table 1 gives an overview of the frequency of tooth root injuries caused by IMF and OP screws in the literature.

The aim of this retrospective study was (1) to analyze the frequency and the location of the affected teeth and to compare IMF and OP screws concerning their risk for tooth root injuries; (2) to detect possible predictive factors for tooth root injuries, such as interdental- and crestal distance, screw length and distance between tooth roots and screws; (3) to evaluate the accuracy of two- (OPTG, orthopantomogram) and three-dimensional (CBCT, cone beam computer tomography) imaging for the diagnosis of tooth root injuries.

2. Methods

For this retrospective-designed study, all electronic health records in the time-period between 01.01.2004 and 02.08.2013 were screened for patients treated with IMF screws and/or OP in the Department of Oral- and Maxillofacial Surgery, University Medical Center Mainz, Germany. All patients with fractures of the maxilla and/or the mandible and after mono- or bimaxillary osteotomies that were treated with IMF screws and/or OP were included to the study. Further inclusion criteria were: fracture <30 mm away from the next tooth root and IMF- or OP screw placed <10 mm away from next tooth root. The following exclusion criteria were applied to analyze the direct association of screw insertion and tooth root injury: patients with “screw-less types” of IMF (e.g., splints and arch bars), patients in whom the postoperative X-ray control (OPTG or CBCT) could not be obtained and cases in which the fracture occurred in a toothless jaw or with a distance >30 mm away from the next tooth root as well as screws that were inserted at a distance >10 mm away from the next tooth root.

For postoperative X-ray controls, either OPTG (Orthophos XG 3D ready, Sirona Dentsply, Bensheim, Germany) or CBCT scans (3DExam, Kavo Dental GmbH, Biberach, Germany) were analyzed. In cases with postoperative OPTG scans, no further measurements could be obtained without a fixed reference object in the exact level of interdental space.

A distance <10 mm between tooth root and inserted screw was defined as an “endangered” tooth. The tooth root injuries seen in the OPTG and CBCT scans were divided into three groups depending on the grade of severity: (1) tooth root-scratch, (2) severe tooth root injury without damage of the dental pulp, (3) severe tooth root injury with damage of the dental pulp (Fig. 1).

Interdental- and crestal distance, and the distance between the tooth roots and the screws were measured. Screw length was taken from the health record and/or the operation report. Otherwise, it was measured/counted in the X-ray scans.

For data acquisition, software Microsoft Excel for Windows (Microsoft Corporation, Redmond, USA) and SAS 9.4 (SAS, Heidelberg, Germany) were used. Data were analyzed descriptively. To evaluate the accuracy between OPTG vs. CBCT concerning the diagnosis of tooth root injuries, Cohens Kappa analysis was performed. κ-values >0.75 were defined to demonstrate a significant accordance, while κ-values <0.75 were defined to demonstrate no relevant accordance. This retrospective analysis was in accordance with the guidelines of the local ethics committee (Ethikkommission Ärztekammer Rheinland-Pfalz, Mainz, Germany).

3. Results

In total, 366 patients (men: 233, women: 133) and 4844 screws were included in the study and postoperative X-ray controls (OPTG and CBCT) were analyzed. OPTG was available for 291 patients and CBCT for 183 patients. In 183 patients, only OPTG was available and in 75 patients, only CBCT was performed. Overall, 3388 teeth could be defined as endangered. For IMF screws, 736 teeth in the CBCT scans and 816 in the OPTG scans were categorized as endangered. For OP, screws endangered 1244 teeth in the CBCT and 1374 teeth in the OPTG scans (Table 2).

Overall, CBCT showed 16 tooth injuries (0.5%) in 13 patients (3.55%) (severity: 8 x grade 1, 5 x grade 2, 3 x grade 3). Nine injuries (56.2%) were caused by IMF screws and 7 injuries (43.8%) were caused by OP screws. Both times (IMF and OP), the premolars were most frequently affected with tooth root injuries (IMF n = 7/9, 77.8%; OP n = 4/7, 57.1%). IMF screws affected more tooth roots in the maxilla (n = 5/9, 55.5%). OP screws exclusively injured tooth roots in the mandible (7/7, 100%).

The OPTG showed 230 tooth root injuries (6.8%) in 107 patients (29.2%). 153 injuries (66.5%) were caused by IMF screws and 77 injuries (33.5%) were caused by OP screws. The IMF screws were mostly in contact with the canines (n = 98/153, 64%). In contrast, OP screws showed more contact to the molars (n = 61/77, 79.2%). IMF screws affected more tooth roots in the maxilla (n = 81/153, 52.9%) and OP screws injured more tooth roots in the mandible (n = 70/77, 90.9%). Fig. 2 summarizes the overall percentage frequency with respect to the location of the respective endangered and injured teeth by IMF and OP screws in the maxilla and the mandible, analyzed in the CBCT and OPTG scans.

With respect to the analysis of predictive factors, in the CBCT scans, the measured interdental distances were smaller in locations where IMF screws were placed (3.35 ± 1.89 mm) than in the

Table 1
Exemplary literature overview concerning the incidence of tooth root injuries caused by IMF and OP screws.

Author	Type of screw	Incidence of tooth root injury (%)	Conclusion
Al-Jandan et al. (2013)	OP screws	*Screw length* teeth 2 mm 4 mm 7 mm - canine 0% 30% 100% - first premolar 0% 18% 100% - second premolar 0% 38% 100% - first molar 0% 14% 100% - second molar 0% 0% 36%	The risk of tooth root injuries significantly increases with the screw length and is decreasing from the canines to the second molars.
Andrei Florescu et al. (2016)	IMF screws	1.13%	Screws for IMF are associated with an extremely low risk for tooth root injuries.
Ansari et al. (2011)	IMF screws	0%	IMF screws have overall a lower complication rate compared to arch bars and should be preferred for IMF.
Bai et al. (2015)	IMF screws	1.8%	The indication to use IMF screws should be examined critically.
Barodiya et al. (2017)	IMF screws	5%	IMF with screws is very useful, even there are some limitations.
Bins et al. (2015)	IMF screws	9%	IMF screws can be recommended for IMF.
Bissada et al. (2011)	IMF screws	13%	IMF screws represent a very suitable alternative to other kinds of IMF, such as arch bars.
Borah and Ashmead (1996)	OP screws	0,47% risk mandible/maxilla 10:3	Tooth root-screw impingement has a high rate of self- regeneration with a low incidence of adverse consequences.
Coburn et al. (2002)	IMF screws	4%	Main complications of IMF screws are screw fractures, tooth root damage and bone sequestra.
Coletti et al. (2007)	IMF screws	4%	Self-drilling IMF screws are a useful tool for IMF, but not without risks and limitations.
Cornelius et al. (2010)	IMF screws	Review: 0.9–13% (% of total screw number) 0.8–50% (% of total patient number)	The preoperative planning and the correct placement of IMF screws with respect to the individual anatomy can decrease the risk of injuries.
Driemel et al. (2005)	OP screws	7.6%	The type and the location of the tooth root injury is relevant for the therapy and the outcome.
Ellis (2011)	OP screws	0–1.5%	The risk of tooth root injury seems to be higher for 2 mini-plates compared to 1 stronger plate.
Fabbroni et al. (2004)	OP screws	27%	The incidence of clinical relevant tooth root damage is very low.
Gorka et al. (2017)	IMF screws	0%	Using screws for IMF is quicker and safer compared to other techniques.
Hartwig et al. (2017)	IMF screws	12.5%	Tooth root injuries are a relevant side effect. Fortunately, the health of the affected teeth is often uncompromised.
Hashemi and Parhiz (2011)	IMF screws	6.5%	IMF screws are very useful and time saving. Accuracy is important to reduce the risk of complications.
Ingole et al. (2014)	IMF screws	22%	Overall, IMF with screws is a safe procedure, time saving and cost effective with good oral hygiene compared to other techniques.
Laurentjoye et al. (2009)	IMF screws	0%	IMF screws have a lot of advantages compared to arch bars.
Nandini et al. (2011)	IMF screws	0%	Root injury is the most important complication of screws for IMF.
Rai et al. (2011)	IMF screws	5.81%	IMF screws allow a better hygiene, reduced operation time and a decreased rate of complications compared to arch bars.
Roccia et al. (2005)	IMF screws	1.5%	IMF screws are a well-established alternative to arch bars. Tooth root damage is the most important side effect.
Roccia et al. (2009)	IMF screws	0%	The use of self-tapping and self-drilling screws for IMF can reduce the risk of tooth root injuries.
Schulte-Geers et al. (2012)	IMF screws	17.1% (0.2% tooth loss, 0.2% root canal treatment, 0.3% persistent pain)	The risk of tooth loss is low. Root injuries often heal without further complications.
van den Bergh et al. (2015b)	IMF screws	0.53%	IMF screws are a superior method compared to arch bars.
West et al. (2014)	IMF screws	28% (14% penetration, 14% close contact)	IMF screws are well tolerated by the patients. The aspect of time-saving does not compensate the high costs.
Widar et al. (2012)	IMF screws	0% drill-free screws 45.3% pre-drilled screws 15.6% after 1-year follow up	Drill-free screws have a significantly reduced risk of tooth root injuries compared to pre-drilled screws.

locations with OP screws (3.42 ± 1.87 mm). For IMF screws, the interdental distance was smaller when the screw led to a tooth root injury (2.79 ± 1.07 mm). In the OPTG scans, the interdental distances in cases of tooth root injuries were smaller (IMF: 3.08 ± 0.87 mm; OP: 2.66 ± 0.98 mm) compared to not-injured cases (IMF: 3.38 ± 2.09 mm; OP: 3.86 ± 2.43 mm), see Fig. 3.

In the CBCT scans, measurement of the crestal distance demonstrated that IMF screws were inserted with a decreased crestal distance (4.78 ± 2.29 mm) compared to OP screws (13.54 ± 5.34 mm). The injuring OP screws (9.4 ± 2.89 mm) were placed with a reduced crestal distance than the non-injuring screws (13.56 ± 5.34 mm). In the OPTG scans, also a decreased crestal distance could be demonstrated for the IMF screws (4.78 ± 2.29 mm) compared to the OP screws (13.54 ± 5.34 mm) (Fig. 4).

In the CBCT scans, the mean length of IMF screws (8.93 ± 1.63 mm) was longer compared to OP screws (4.31 ± 1.37 mm). The length of IMF screws was longer in the group of injured teeth (9.0 ± 1.22 mm) compared to non-injured teeth (8.93 ± 1.64 mm). Concerning OP screws, reverse results could be found (Fig. 5).

The measurement of the distance between tooth roots and screws revealed that IMF screws were on average placed closer to the tooth roots (1.06 ± 1.04 mm) than OP screws (4.53 ± 2.93 mm). In the mandible, screws were closer to the tooth roots (IMF: 1.01 ± 0.8 mm; OP: 4.24 ± 2.87 mm) than in the maxilla (IMF:

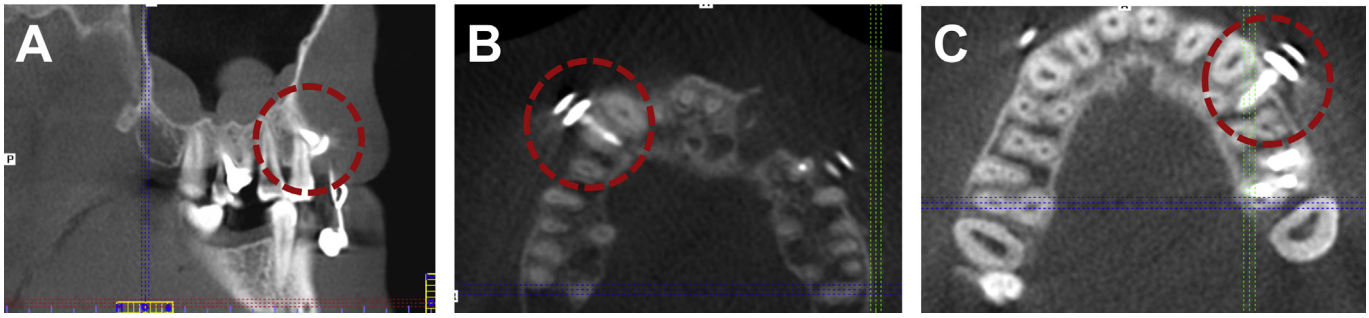

Fig. 1. CBCT examples of the different grades of severity of tooth root injuries. (A) grade 1: root scratch of the first premolar of the right upper jaw (red circle), (B) grade 2: severe injury without damage of the dental pulp of the first premolar of the right upper jaw (red circle), (C) grade 3: severe injury with damage of the dental pulp of the first premolar of the left upper jaw (red circle).

Table 2
Overview of the endangered and injured tooth roots after IMF and OP screw insertion in the OPTG and CBCT scans.

	DVT				OPTG				total	
	Endangered but not injured teeth		Injured of total endangered teeth		Endangered but not injured teeth		Injured of total endangered teeth			
	N	%	N	%	N	%	N	%	N	%
IMF	736	51.4	9	0.6	816	57.0	153	10.7	1432	100.0
Plate osteosynthesis	1244	63.6	7	0.4	1377	70.4	77	3.9	1956	100.0
total	1980	58.4	16	0.5	2193	64.7	230	6.8	3388	100.0

1.14 ± 1.24 mm; OP: 4.94 ± 2.93 mm). An overview of the distance between tooth roots and screws is presented in Fig. 6. In cases of tooth root injury, there was a significant correlation between the interdental space and the tooth-screw distance ($\kappa = 0.48$; $p < 0{,}001$). An increasing interdental distance resulted in an increasing distance between the screw and the tooth root (Fig. 7).

The comparison of both imaging methods, OPTG vs. CBCT, demonstrated that many of the injuries that were seen in the two-dimensional OPTG (n = 230) could not be verified in the three-dimensional CBCT (n = 16). The frequency of tooth root injuries occurs up to four times in the same patient when exclusively OPTG was used. The sensitivity and specificity for both systems (OPTG and CBCT), for IMF and OP screws, was overall 88% and 91% (IMF: sensitivity 100%, specificity 85%; OP: sensitivity 83%, specificity 93%), $\kappa = 0.12$. Fig. 8 demonstrates two exemplarily OPTG and CBCT scans of a tooth root injury.

Four of the patients who were detected as injured in the CBCT scans were re-evaluated in a follow-up check (tooth root injury severities: 1 x grade 1, 1 x grade 2, 2 x grade 3). In three patients, the affected teeth were non-vital. One of them had to be extracted and 2 teeth got root canal treatment. One patient showed hypersensitivity without any necessity for further treatment.

4. Discussion

Tooth root injuries by IMF and OP screws are a known risk but the clinical significance is controversially discussed since screws for IMF and OP are associated with a large number of relevant advantages for the affected patients, since there is an overall low frequency of tooth root injuries – especially with a high severity, and since affected tooth roots demonstrate good prospects for recovery (Borah and Ashmead, 1996; Fabbroni et al., 2004; Asscherickx et al., 2005; Kadioglu et al., 2008; Schulte-Geers et al., 2012). In this context, the term recovery can be discussed controversially and in more detail since the presented literature is not dealing with a clear definition. In the presented study, two patients needed a root canal treatment, and in one patient a tooth extraction was necessary. In one patient no further treatment was necessary. To conclude, acceptable prospects of recovery after tooth root injuries by screws might be obtained in combination with additional care and treatment. Unfortunately, the current analysis is limited by an overall low frequency of tooth root injuries.

The results of this study demonstrated that IMF screws caused an increased number of tooth root injuries compared to OP screws. One explanation might be that IMF screws are on average longer and placed closer to the tooth roots than OP screws. Further, IMF screws are often inserted through the intact oral mucosa while OP screws are placed in the periosteum free bone with a sufficient view on the tooth roots outlines and courses. Next, OP screws are often placed with an increased crestal distance compared to IMF screws, which might also reduce the risk of tooth root injuries.

Most of the tooth root injuries in this study were seen in the mandible. One possible explanation might be the thicker cortical bone in the mandible. Therefore, the outlines of the tooth roots cannot be seen in high detail compared to the maxilla (Al-Jandan et al., 2013). The canines and the premolars could be identified to have the highest risk for tooth root injuries. This observation could be based on two different circumstances: on the one hand, a small interdental distance in these areas, and on the other hand, on the clinical observation that IMF screws are most frequently placed in these areas (Roccia et al., 2009; Al-Jandan et al., 2013). These observations could be confirmed in the presented study. Most of the tooth root injuries detected by CBCT scan were identified in the premolar region where IMF and OP screws are most frequently inserted. Contrarily, two-dimensional OPTG demonstrated the most frequent tooth root injuries by IMF screws in the canines and OP screws in the molar region, IMF screws more frequently in the maxilla, and OP screws more frequently in the mandible. Poggio et al. reported that the largest distances were found in the maxilla between the canines and the first premolars and between the first and second premolar. In the mandible, the largest distance was found between the first and second premolar (Poggio et al., 2006). Contrarily, Deguchi et al. reported the region around the first molars to be the safest position for screw insertion (Deguchi et al.,

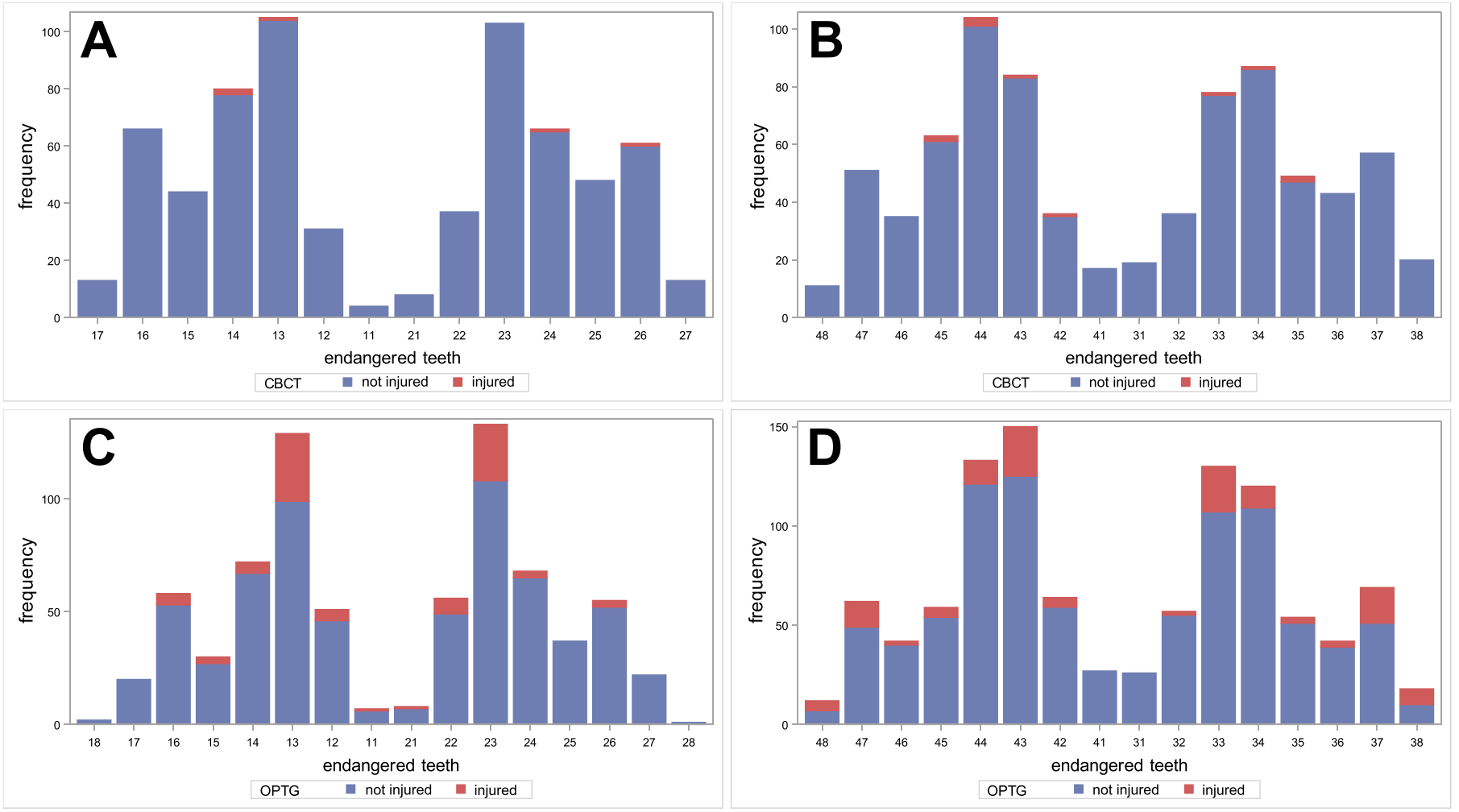

Fig. 2. Overview of the overall frequency of the respective endangered and injured teeth by IMF and OP screws in the maxilla (A, C) and the mandible (B, D), analyzed in the CBCT (A, B) and OPTG (C, D) scans. X-axis: tooth position, Y-axis: percentage frequency (%).

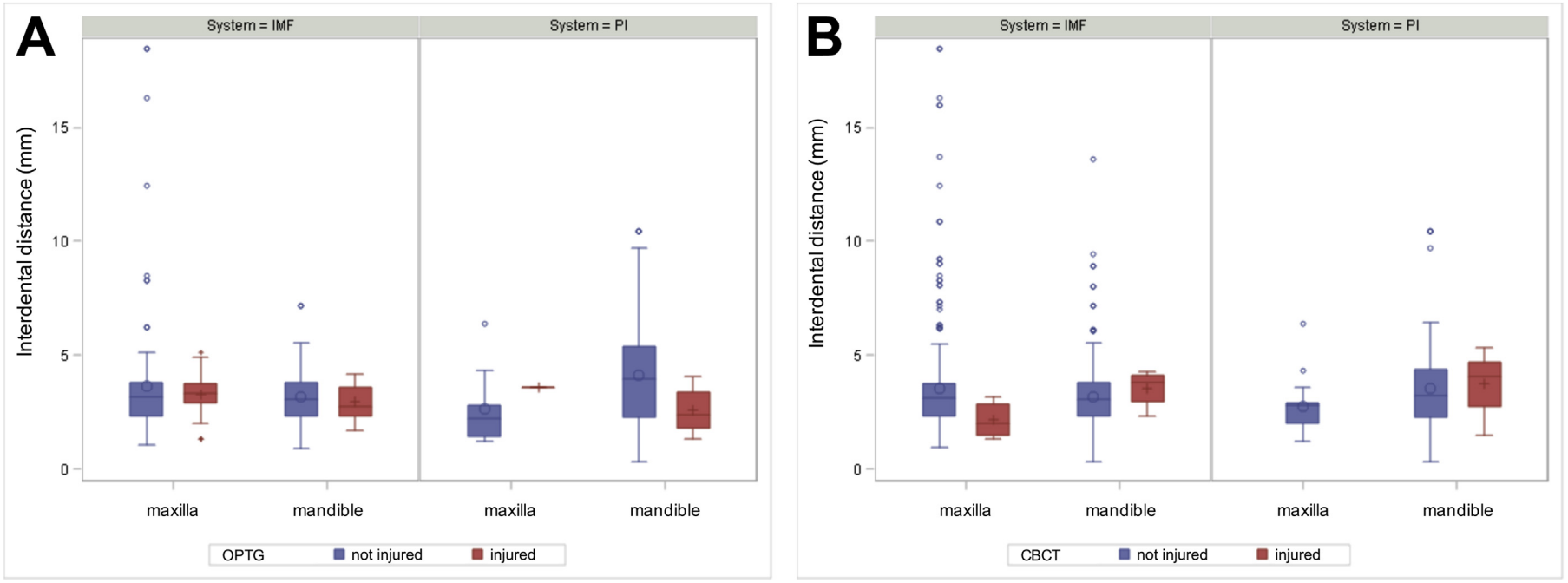

Fig. 3. Overview of the measured interdental distances for the inserted IMF and OP screws (PI) in the OPTG (A) and CBCT scans (B). X-axis: maxilla and mandible, Y-axis: interdental distance (mm).

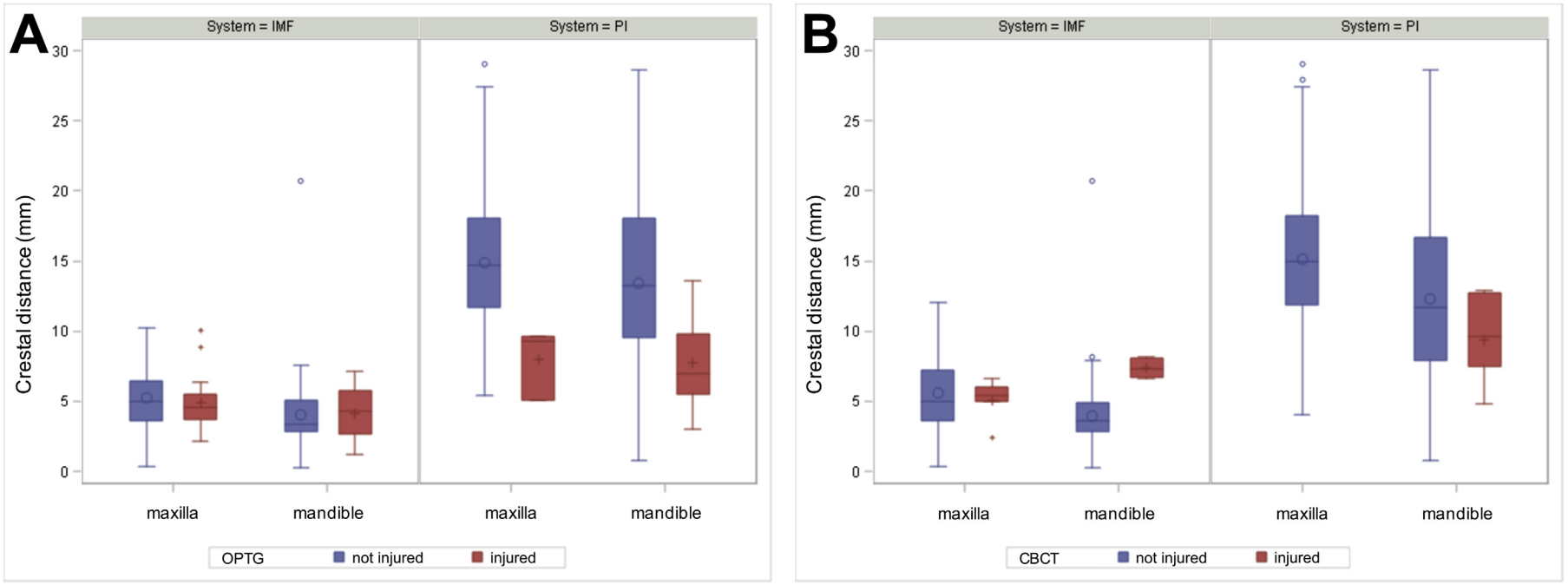

Fig. 4. Overview of the measured crestal distances for the inserted IMF and OP screws (PI) in the OPTG (A) and CBCT scans (B). X-axis: maxilla and mandible, Y-axis: interdental distance (mm).

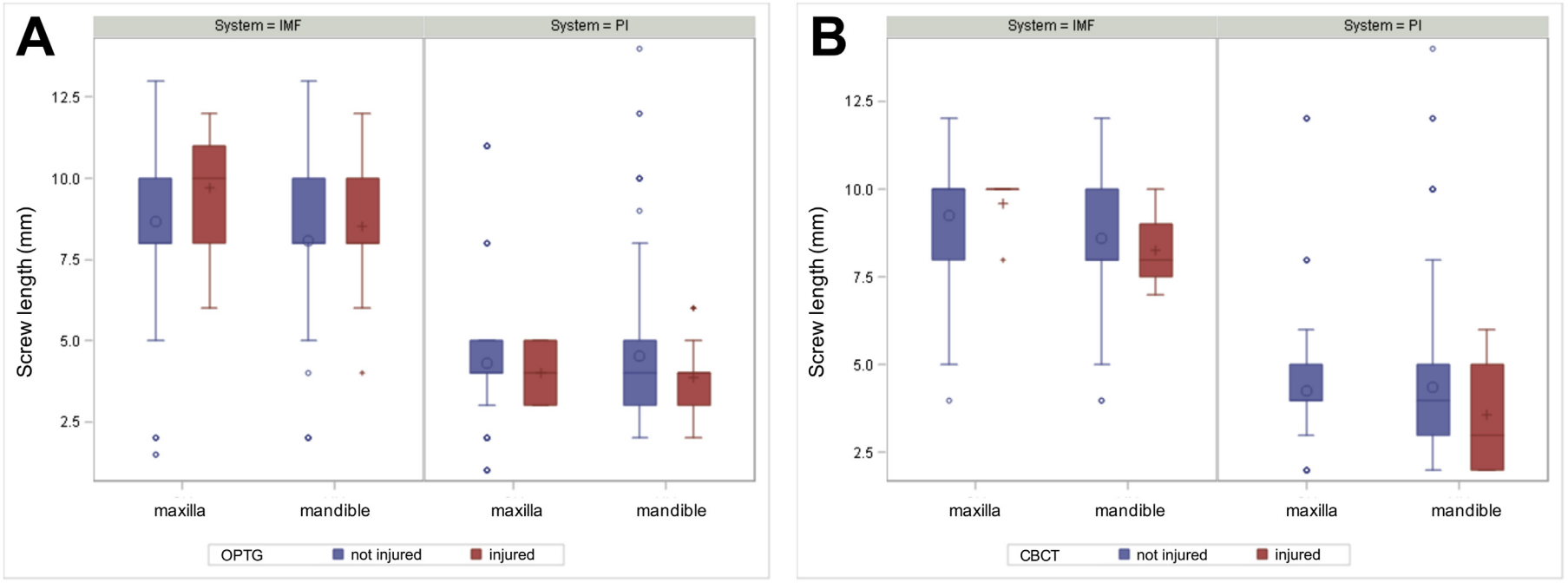

Fig. 5. Overview of the measured screw length for the inserted IMF and OP screws (PI) in the OPTG (A) and CBCT scans (B). X-axis: maxilla and mandible, Y-axis: interdental distance (mm).

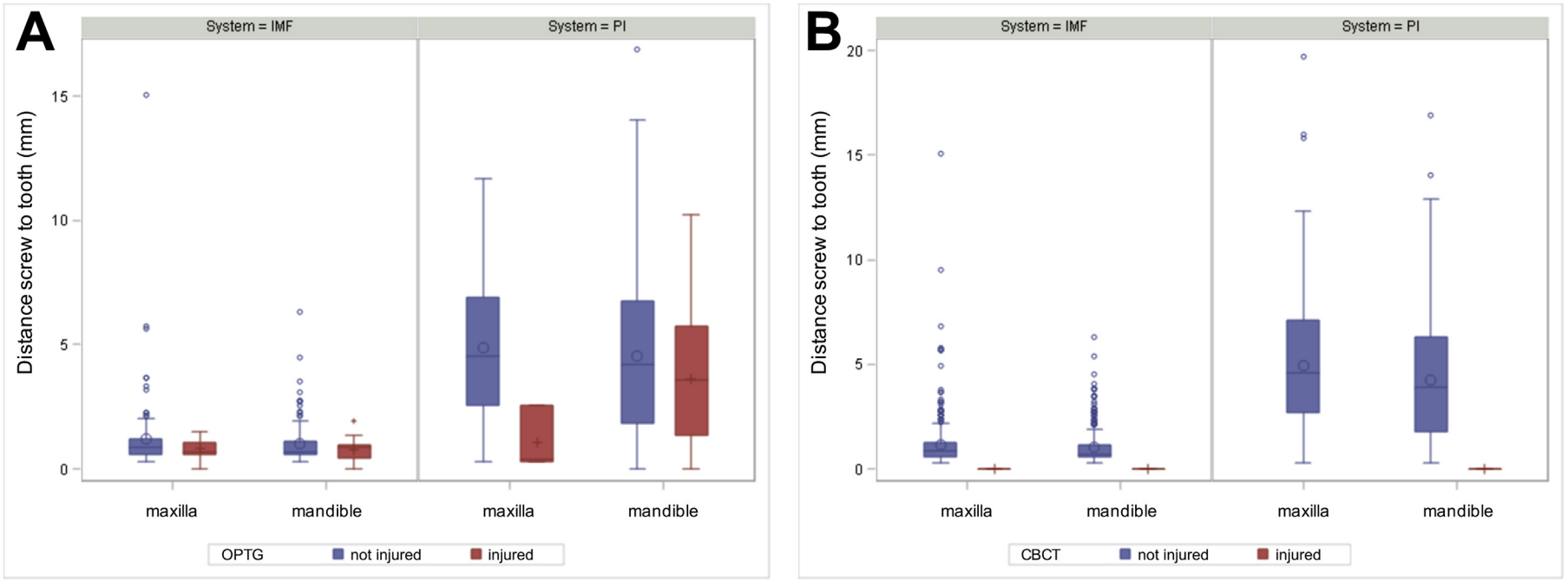

Fig. 6. Overview of the measured distance screw to tooth for the inserted IMF and OP screws (PI) in the OPTG (A) and CBCT scans (B). X-axis: maxilla and mandible, Y-axis: interdental distance (mm).

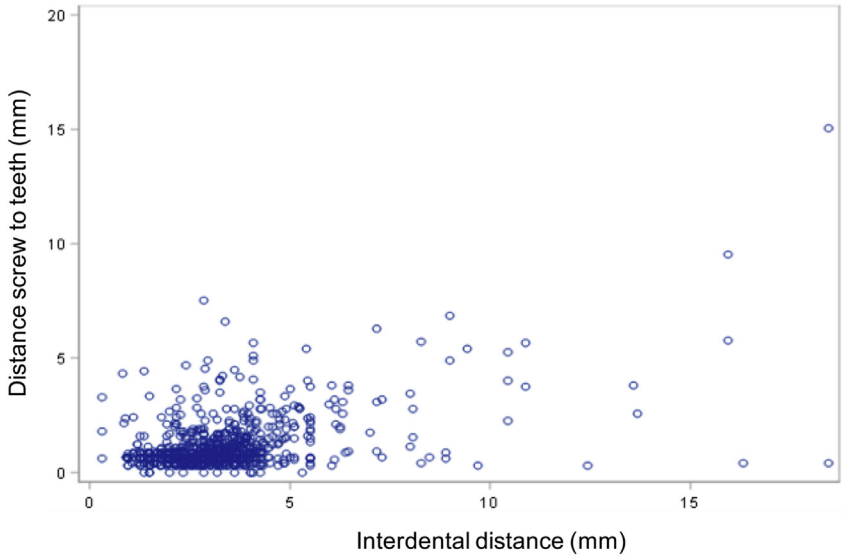

Fig. 7. Correlation of the screw to tooth root distance and the interdental distance. X-axis: interdental distance (mm), Y-axis: distance screw to tooth root (mm).

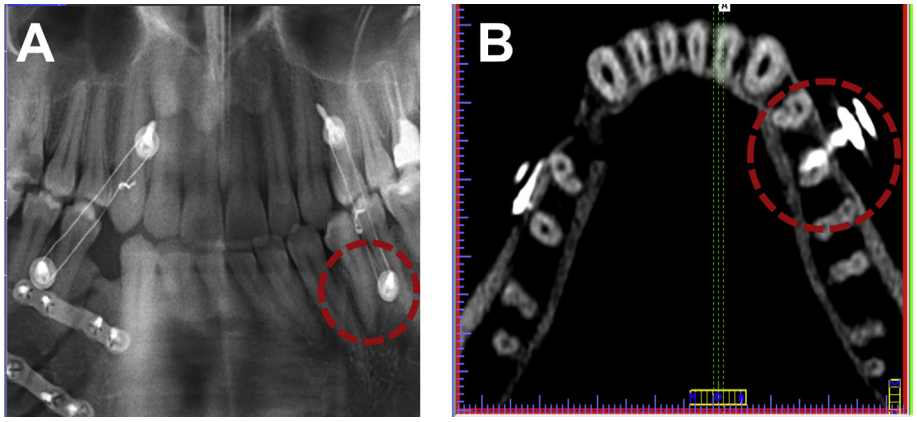

Fig. 8. Exemplary OPTG (A) and CBCT (B) scans with a tooth root injury (grade 3) of the second premolar of the left lower jaw (red circles). The OPTG scan (A) only allows the presumption of a tooth root injury. The CBCT scan (B) enables the reliable diagnosis of the tooth root injury, and further, a severity assessment.

2006). McGinn and Fedok reported that the safest place is around the canines (McGinn and Fedok, 2008). In addition to these findings, the presented study demonstrated that the interdental distance that was measured by CBCT scan can be considered as of promising prognostic value. For both OPTG and CBCT scans, the measured interdental distances were smaller in cases of tooth root injuries compared to non-injured roots. Further, this was confirmed by the observation that an increased distance between the screw and the tooth root was found in cases with an increased interdental distance. To date, there exists no limit concerning the interdental distance that can be associated with an increased risk for tooth root injuries. This topic could be investigated in a subsequent study. Possible risk factors for tooth root injuries are the diameter and length of the screw, the position, the angle and direction of insertion and pre-drilling of screws (Fabbroni et al., 2004; Cornelius and Ehrenfeld, 2010; Widar et al., 2012). In this context, deviation of 8 degrees of the insertion angle of a screw with a length of 8 mm results in a deviation of the screw tip of more than 1 mm (Estelita Calvalcante Barros et al., 2006). With respect to finding the correct diameter, length, position and direction of insertion, a preoperative CT (or CBCT) scan is recommendable and might help to overcome the mentioned risk factors (Wu et al., 2012). Good anatomical skills of the tooth roots and especially their position can also reduce the risk of tooth root injuries (Wu et al., 2012). Tooth root injuries are more frequent in pre-drilled screws than in self-drilling screws. Consequently, self-drilling screws might be preferred (Coletti et al., 2007; Roccia et al., 2009; Widar et al., 2012). These findings are set in contrast to the results of the presented study. Overall, 56.2% of the injuries were caused by IMF screws and 43.8% of the injuries were caused by OP screws in a comparable total number of cases. Therefore, the question remains unclear whether pre-drilling screws are associated with an increased frequency of tooth root injuries in comparison to self-drilling screws. One possible explanation for these findings might be that surgeons are nowadays paying more attention to the planning and to the surgical procedure when using pre-drilling screws, knowing well about the possible risk of tooth root injuries, especially by the drill bit. Some authors reported that self-drilling screws have the advantage that the surgeon can feel the differences concerning the turning resistance. Penetrating a tooth root would suddenly increase the resistance compared to the soft cortical bone (Deguchi et al., 2006; Hembree et al., 2009; Renjen et al., 2009; Lim et al., 2013). Widar

et al. reported that the insertion on the border between fixed and mobile gingiva can be considered as a safe place for screw insertion (Widar et al., 2012).

With respect to the diagnosis of tooth root injuries, some authors reported a high rate of false-positive results when OPTG is used (Hembree et al., 2009; Lim et al., 2013). This is also reflected in the present study. Most of the tooth root injuries seen in the OPTG could not be verified in the CBCT. CBCT showed no false-positive results. One explanation might be that the OPTG can wrongly decrease or increase the interdental space in dependence from the incident angle on the jaw bone, giving the surgeon wrong information concerning the bone space available to place the screw (Wu et al., 2012). Therefore, 3D X-ray such as CBCT can be recommended to detect tooth root injuries (Deguchi et al., 2006).

With respect to the treatment, the prognosis and the outcome of affected teeth, root injured teeth demonstrate overall good prospects of a cure. The long-term outcome is especially dependent from the severity of the injury (Hashemi and Parhiz, 2011; Widar et al., 2012; Ingole et al., 2014). Ingole et al. found 8/8 non-vital teeth with a high severity of injury and 1/16 non-vital teeth with a low severity of injury after a follow-up period of 4 weeks with a need for root canal treatment (Ingole et al., 2014). Unfortunately, root canal treatment in injured tooth roots has been reported to be difficult (McCabe and Kavanagh, 2012). Lim et al. reported that root canal treatment is sometimes not enough and that additional tooth root resection is sometimes additionally required (Lim et al., 2013). In another study, 0/13 injured and initially non-vital teeth needed a further treatment. The authors concluded that an initial negative vitality test should not be the indication for a root canal treatment (Borah and Ashmead, 1996). To summarize, non-vital teeth in cases of tooth root injuries by screws have a high level of regeneration. If dental pulp damage is demonstrated in the CBCT, root canal treatment can be the treatment of choice.

5. Conclusions

The results underline the risks of tooth root injuries caused by IMF and OP screws. However, the incidence found was very low. Screws for IMF and OP can be considered as a safe procedure concerning the risk of tooth root injuries. The risk is rather small compared to the advantages of the screws. With respect to the detection of tooth root injuries, CBCT should be the method of choice.

Declaration of interests

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