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Contribution of cone-beam computed tomography in the decision of surgical management for bone lesions of the maxillofacial region

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ABSTRACT

The aim of this study was to evaluate the contribution of cone-beam computed tomography (CBCT) in the decision of surgical management for bone lesions of the maxillofacial region. It is a retrospective cross-sectional observational study that includes a sample of panoramic radiography (PR) and CBCT from patients with some type of bone lesion in the maxillofacial region. PR and CBCT images were evaluated by three previously assessed examiners, specialists in oral and maxillofacial surgery. Each image was evaluated randomly, and a surgical procedure was suggested, initially in PR and then in CBCT. The obtained results were submitted to the McNemar test to evaluate the frequencies of changes in the surgical management between the first and the second evaluation in PR and CBCT, and intra-examiner and inter-examiner agreements were analyzed by the Cohen's kappa test. The level of significance was set at 5% ($p < 0.05$). Intra-examiner agreement increases when CBCT is used. Inter-examiner agreement was low, independently of the evaluated exam, which shows that the choice of treatment plan is examiner-dependent and not exam-dependent. CBCT increases the certainty of the professional in the evaluation of the bone lesions of the maxillofacial region; however, it does not change the indication of the treatment type.

1. Introduction

Following the principles of semiology, the images for diagnosis should be prescribed only after the revision of the medical history of the patient and complete clinical exam. Radiographic exam is highly recommended when it brings a benefit to the patient and a significant impact on clinical care (American Dental Association Council on Scientific Affairs, 2012).

Panoramic radiography (PR) provides an overview of bone lesions. However, computed tomography (CT) has been advocated as a preferential imaging system in the investigation of details, such as the relationship of lesions with the buccal and lingual cortices, relationship with anatomical structures, more precise evaluation of lesion dimension, and relationship with adjacent teeth, internal structure, cortical expansion, and bone erosion (Avinash et al., 2007; Boeddinghaus and Whyte, 2008).

Many factors have led to greater use of cone-beam computed tomography (CBCT) in dentistry, such as easy handling and easy positioning of the patient, the cost of the exam, and easy installation of the equipment as well as the reduction of radiation exposure compared to multislice computed tomography.

In oral surgery, the main indications for CBCT exam include dental extraction, localization of unerupted teeth and mandible canal, implant planning, bone lesion evaluation, diagnosis of

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fractures, orthognathic surgery planning, and evaluation of the maxillary sinuses and temporomandibular joint disorders (Ahmad et al., 2012).

To assist in the establishment of criteria for indication of the most appropriate imaging exam for each case, international agencies such as the Radiation Control Directorate of the Health Department of South Africa (Noffke et al., 2011), the American Dental Association (American Dental Association Council on Scientific Affairs, 2012), the European Academy of Maxillofacial Radiology (Sedentex, 2012), and the Swiss Society of Dentomaxillofacial Radiology (Dula et al., 2014, 2015) have published guidelines to avoid the abuse of exam requests. Specifically, regarding the indication of CBCT for bone lesions, the panel of specialists (Pittayapat et al., 2014) recommends that CBCT be indicated by the surgeon who will effectively treat the patient.

Therefore, as for any radiographic image, CBCT should be indicated based on the history and individual exam of each patient. The exam should show the potential benefit to the patient to the detriment of radiation exposure. The indication should consider the possibility of treatment and necessarily be based on scientific evidence.

For the orientation of the professionals at the moment of requesting the tomographic image, the objective of this study was to evaluate the contribution of CBCT in the decision of the treatment plan for bone lesions of the maxillofacial region. For this purpose, a comparison was made between PR and CBCT exams for the surgical decision. The hypothesis of the study is that CBCT can alter the surgical management.

2. Materials and methods

This study was approved by the Research Ethics Committee of the Federal University of Goiás (under number 653.291/2014). This is a retrospective cross-sectional observational study, in which the guidelines for observational cross-sectional studies Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (van den Brekel et al., 1998) were followed. The sample was obtained by the technique of convenience sampling in a database of PR and CBCT exams of patients who presented with bone lesions in the maxillofacial region from 2000 to 2016, coming from the Goiano Center for Mouth Diseases of the Federal University of Goiás (CGDB/UFG), the Center for Dental Radiology of the University Hospital of the University of Brasília (HUB), and a private maxillofacial surgery clinic; in total, 32 medical records were selected.

The cases of the patients who had previously authorized the use of their documentation for the research were included in the sample. All the files and exams of the patients who underwent fan-beam computed tomography, the cases with incomplete records, those with absence of pathological diagnosis, or those who underwent any surgical procedure in the region of interest prior to the radiographic exam, including incisional biopsy, were excluded from the sample.

For the analysis of panoramic radiographs, Windows Photo-Gallery software was used. For the analysis of the tomographic images, InVivo Software 5.3.2 was used. CT exams, in DICOM (Digital Imaging Communication in Medicine) format, were examined in the entire volume, analyzing each cut individually and in all planes: axial, coronal, and sagittal.

Three independent and previously assessed maxillofacial surgeons, professors, and maxillofacial surgery specialists with clinical experience of 28, 5, and 12 years evaluated all the images in a quiet and darkened environment using a computer with adequate configuration: 28" Ultra screen HD LED monitor with 3840 × 2160 pixel resolution, 16 ms response time, 0.27 mm pixel pitch, 178° horizontal and vertical viewing angle, 300 cd/m^2 brightness and 850:1 contrast, CPU with core i7 900 series compatible with multi-core processor, 8 GB RAM, ATI Radeon HD 6970 or NVIDIA GeForce GTX-580 GPU/Graphics Card, 500 GB HD, and Windows10 64bit OS operating system. During the analysis of images, the examiners had access to the full volume in the CBCT images. The exams were allocated into two groups ("PANORAMIC" and "TOMOGRAPHY") and randomly arranged. First, the panoramic radiograph was made available. In the second phase with an interval of at least 15 days, the analysis of the tomographic images was performed. The anatomopathological result was made available for each case, and the examiner had to choose the most appropriate surgical procedure for each analyzed case, among: 1) enucleation, 2) marsupialization, 3) marsupialization followed by curettage enucleation, 4) resection, and 5) others. After the next 15 days, all the exams were evaluated again (T2) by the three examiners. The calibration was performed using three exams that were excluded from the sample.

The data were analyzed using SPSS® software (Version 21; SPSS Inc., Chicago, IL, USA). Cohen's kappa coefficient was used to evaluate intra-examiner and inter-examiner agreement. The McNemar test ($p < 0.05$) was used to compare the frequencies of changes in the surgical management between the first and the second evaluation in PR and CBCT for each examiner.

3. Results

The suggested surgical procedures of each examiner in the evaluation of PR and CBCT in the first and the second evaluation are shown in Table 1.

In Table 1, it can be observed that the most aggressive surgical procedure was adopted at least six times in five cases (1, 13, 17, 23, and 24). The largest lesions led to a more conservative choice, such as marsupialization previous to enucleation.

Table 2 shows higher values of intra-examiner agreement in CBCT (kappa: 0.830–0.766 - 0.617) when compared to the choice of surgical management after PR analysis (kappa: 0.758–0.585 - 0.425), for the three assessed examiners.

Table 3 shows the results of inter-examiner agreement in the first and the second evaluation using PR. The agreement between examiners 1 and 2 was mild in the first evaluation and moderate in the second evaluation. The agreement between examiners 1 and 3 was mild in both evaluations. The agreement between examiners 2 and 3 was very mild in the first evaluation and moderate in the second evaluation.

Table 4 shows the results of inter-examiner agreement in the first and the second evaluation using CBCT. The agreement between examiners 1 and 2 was moderate in the first evaluation and mild in the second evaluation. The agreement between examiners 1 and 3 was mild in both evaluations. The agreement between examiners 2 and 3 was mild in the first evaluation and very mild in the second evaluation.

The agreement between the three examiners, independently of the evaluated examination, PR or CBCT, was generally low. Figs. 1 and 2 show a PR and CBCT of the same case exemplifying the agreement regarding the indication of surgical treatment by the three examiners.

It could be observed that there was no statistically significant difference for the changes in the choice of the surgical management for bone lesions of the maxillomandibular region (Table 5) in relation to the evaluated exam and the examiner.

4. Discussion

The objective of this study was to add information on the correct indication of imaging tests to establish the surgical management

Table 1
Surgical procedures suggested in the first (T1) and second evaluation (T2) of each examiner.

	Final diagnosis	Examiner 1				Examiner 2				Examiner 3			
		PR		CBCT		PR		CBCT		PR		CBCT	
		T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
1	Metastatic Tumor	R	R	R	R	R	R	R	R	R	R	R	R
2	Fibro-osseous Lesions	E	E	E	E	EC	EC	EC	EC	E	EC	E	E
3	Ameloblastoma	EC	EC	ME	ME	R	R	R	R	EC	EC	ME	ME
4	Compound Odontoma	E	E	E	E	E	E	E	E	EC	E	E	EC
5	KOT	ME	ME	EC	EC	ME	ME	EC	EC	EC	EC	E	E
6	Fibro-osseous Lesions	E	EC	O	O	EC	EC	EC	EC	E	EC	E	E
7	Residual Cyst	E	E	E	E	E	E	E	E	E	E	E	E
8	Cystic Lesion	EC	ME	EC	EC	E	E	E	EC	EC	E	ME	ME
9	Aneurysmatic Bone Cyst	E	E	EC	EC	EC	EC	EC	EC	O	EC	EC	EC
10	KOT	E	E	EC	EC	ME	ME	EC	ME	E	EC	EC	EC
11	Paradental Cyst	E	E	ME	ME	ME	EC	E	EC	R	E	E	EC
12	Unicystic Ameloblastoma	R	ME	ME	ME	ME	ME	ME	ME	R	R	R	R
13	Myxoma	R	R	R	R	R	R	R	R	EC	R	R	R
14	CGCG	R	E	ME	ME	EC	EC	EC	EC	ME	R	EC	E
15	Cyst	ME	ME	ME	EC	E	ME	ME	EC	R	ME	ME	ME
16	Osteonecrosis	O	O	O	R	EC	O	O	O	R	E	O	O
17	Cemento-ossifying Fibroma	R	R	R	R	EC	R	R	R	R	R	R	R
18	Radicular Cyst	E	E	EC	EC	E	E	E	E	E	E	E	EC
19	KOT	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	M	M
20	Cyst	E	E	EC	EC	E	ME	E	ME	E	E	M	M
21	KO	ME	ME	EC	EC	M	ME	ME	ME	ME	ME	ME	ME
22	Osteoma	O	O	O	O	O	O	O	O	R	R	E	E
23	Osteoma	O	O	R	R	O	R	R	R	R	R	O	O
24	Osteoma	O	E	R	R	O	R	R	R	R	E	E	E
25	KO	EC	EC	EC	EC	EC	EC	EC	EC	EC	EC	ME	ME
26	Radicular Cyst	EC	EC	EC	EC	E	E	E	ME	E	E	E	EC
27	Chronic Abscess	EC	EC	EC	EC	O	R	O	O	ME	ME	ME	ME
28	Osteomyelitis	O	O	O	O	O	O	O	O	ME	ME	ME	O
29	KO	E	E	EC	EC	M	M	ME	ME	EC	EC	E	EC
30	KO	M	ME	M	ME	M	ME	ME	ME	M	ME	M	ME
31	Radicular Cyst	EC	EC	E	EC	E	E	E	E	E	EC	EC	EC
32	KO	E	E	EC	EC	M	ME	O	O	EC	EC	E	EC

*Surgical procedures: E (enucleation), M (marsupialization), ME (marsupialization + enucleation), EC (enucleation + curettage), R (resection), and O (other).
CGCG = Central Giant-cell Granuloma, KO = Keratocystic Odontogenic.

Table 2
Intra-examiner concordance for PR and CBCT.

Examiners	PR (PRt1×PRt2) Kappa (concordance)	CBCT (CBCTt1xCBCTt2) Kappa (concordance)
Examiner 1	0.758 (substantial)*	0.830 (almost perfect)*
Examiner 2	0.585 (moderate)*	0.766 (substantial)*
Examiner 3	0.425 (moderate)*	0.617 (substantial)*

*$p < 0.001$; PRt1 = PR in the first evaluation; PRt2 = PR in the second evaluation, CBCTt1 = CBCT in the first evaluation; CBCTt2 = CBCT in the second evaluation.

Table 3
Inter-examiner Concordance of PR in first and second evaluation.

Examiners	PRt1 Kappa (concordance)	PRt2 Kappa (concordance)
1 × 2	0.306 (mild)*	0.415 (moderate)*
1 × 3	0.334 (mild)*	0.395 (mild)*
2 × 3	0.127 (very mild)**	0.405 (moderate)*

*$p < 0.05$; **$p = 0.104$ (no significance); PRt1 = PR in the first evaluation; PRt2 = PR in the second evaluation.

for bone lesions in the maxillofacial region, especially CBCT, which is often mechanically prescribed without taking into account the actual impact on clinical management and radio-protection principles.

The intra-examiner agreement results found in this study presented moderate values (kappa: 0.758–0.585 - 0.425) when the examiners evaluated PR. When evaluating CBCT, agreement values improved substantially for all examiners (kappa: 0.830–0.766 - 0.617). That is, CBCT exam provided additional data, which led to greater consistency regarding the type of indicated treatment.

Table 4
Inter-examiner Concordance of CBCT in first and second evaluation.

Examiners	CBCTt1 Kappa (concordance)	CBCTt2 Kappa (concordance)
1 × 2	0.415 (moderate)*	0.391 (mild)*
1 × 3	0.296 (mild)*	0.234 (mild)*
2 × 3	0.301 (mild)**	0.175 (very mild)*

*$p < 0.05$; CBCTt1 = CBCT in the first evaluation; CBCTt2 = CBCT in the second evaluation.

When using CBCT, the degree of intra-examiner agreement improves, agreeing with the studies that state CBCT provides important additional information, such as the possibility of three-dimensional (3D) evaluation of the whole extent of the lesions (Pauwels et al., 2012) and underestimation of the lesion size in PR (Lurie, 2009; Koong, 2012; Lim et al., 2018).

Gohel et al. (2016) studied the characteristics of PR and CBCT in the descriptions of various lesions, and in all the cases (root cyst, residual cyst, dentigerous cyst, nasopalatine cyst, and simple bone cyst), CBCT presented less distorted and more real images in relation to the cyst extent and/or their expansion, even in the bucco-lingual aspect. In this study, the cases that presented divergence in the decision about the surgical management were very often associated with more invasive procedures.

Hendrikx et al. (2010) and Momin et al. (2009) compared CBCT and panoramic radiography in the assessment of mandibular

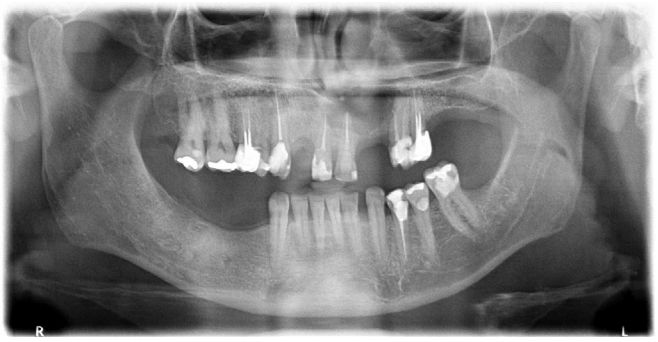

Fig. 1. Panoramic radiograph with a lesion in the left anterior maxilla region.

invasion by carcinoma. They found high sensitivity on diagnosis based on CBCT. However, in cases of oral carcinoma or any malignant lesions, imaging examinations must provide key information for the adequate staging of oral cancer patients, such as depth or extent of invasion, bone invasion and evaluation of regional lymph nodes. These imaging modalities include multislice CT, MRI, nuclear medicine scintigraphy, and positron emission tomography (Figueiredo et al., 2010). CBCT should not be the imaging choice in management of patients with oral carcinoma.

In addition to helping to define the differential diagnosis, PR and CBCT exams should evaluate the extent and complexity of the lesion and guide patient follow-up (von Elm et al., 2014). Moreover, as any other method of diagnosis, these exams need to be extensively studied in order to avoid unnecessary indications.

Boeddinghaus and Whyte (2008) stated that CBCT and especially MSCT allow the differentiation between cysts and tumors, in addition to presenting better spatial resolution and contrast, allowing more accurate measurements regarding the lesion dimension, the relation with adjacent teeth, internal structure, cortical expansion, and bone erosion. In our study, lesions of various dimensions were evaluated. It could be observed that in some cases of cysts, which are smaller diameter lesions, there was also a tendency to choose "more aggressive" surgical techniques in CBCT evaluations, when compared to PR, suggesting that CBCT presents more reliable information regarding the lesions' characteristics.

Table 5
Frequencies of changes in surgical management between the first and the second evaluation in PR and CBCT for each examiner (McNemar test).

Examiner 1				
Surgical management		CBCT		
		No change	Change	Total
PR	No change	23	3	26
	Change	5	1	6
	Total	28	4	32
p = 0.727				
Examiner 2				
Surgical management		CBCT		
		No change	Change	Total
PR	No change	18	3	21
	Change	8	3	11
	Total	26	6	32
p = 0.227				
Examiner 3				
Surgical management		CBCT		
		No change	Change	Total
PR	No change	13	5	18
	Change	9	5	14
	Total	22	10	32
p = 0.424				

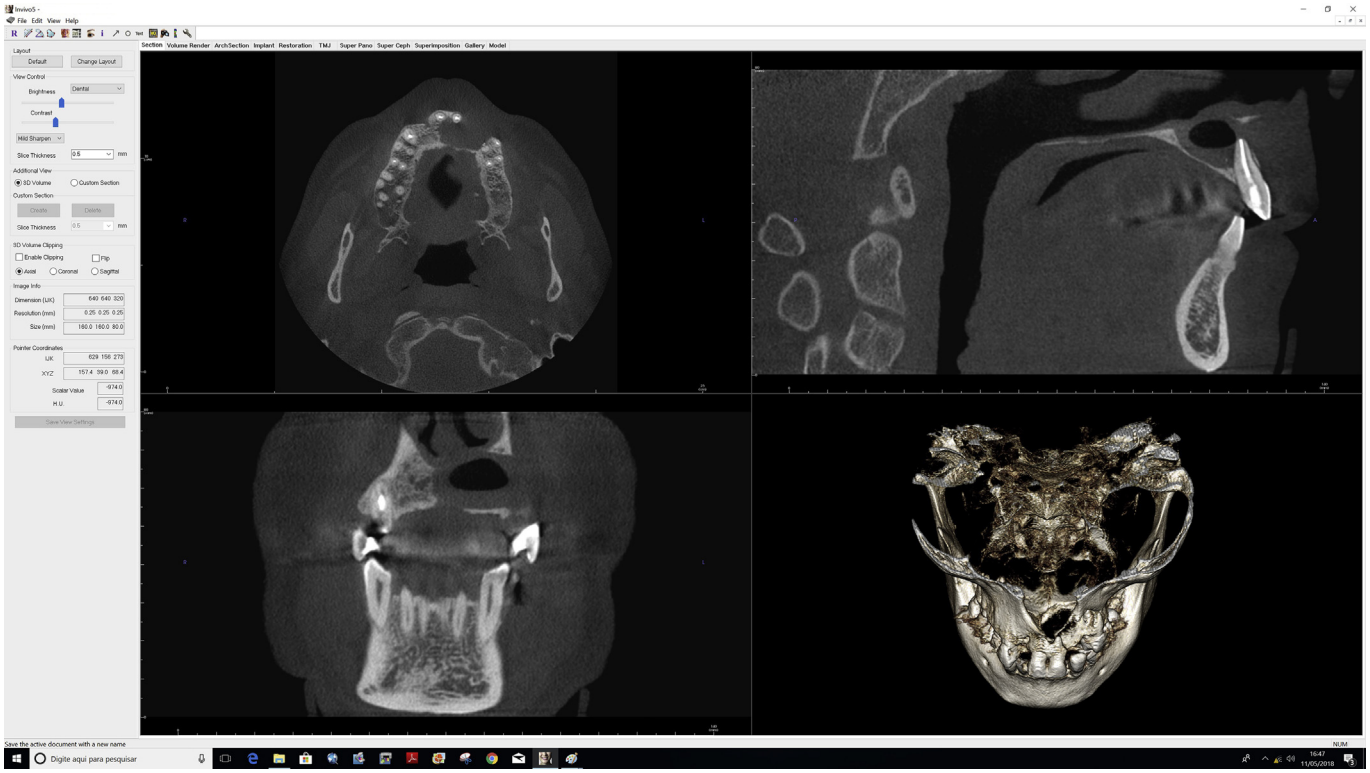

Fig. 2. (CBCT of the same case shown in Fig. 1) exemplify the agreement regarding the indication of surgical treatment by the three examiners.

In the correct prescription of the imaging exam, in addition to considering the as low as reasonably achievable (ALARA) principles, the term as low as diagnostically acceptable (ALADA) (Jaju and Jaju, 2015) has been proposed, making an appeal for quality consideration of the image and the use of CBCT with scientific evidence. Besides that, the cost of the exam, the type of required information, and even the professional's training and experience should be considered (Cotti, 2010; Jaju and Jaju, 2015).

In the inter-examiner evaluation, the agreement between the three examiners, independently of the evaluated examination, PR or CBCT, was generally low, demonstrating that the exam itself does not influence the decision of the surgical management, that is, the decision is probably more examiner-dependent than test-dependent. This fact may be associated with the diversity in the professional experience of the examiners. For example, Examiner 1, with 28 years of experience, showed greater agreement for both evaluated exams. In a different way, we could say that the examiners did not show great agreement among themselves, but when CBCT was used, there was greater agreement in the judgment itself.

When comparing the frequencies of changes in the surgical management between the first and the second evaluation in PR and CBCT for each examiner, we did not find statistically significant differences between the two exams in the change in the decision of the surgical management for bone lesions of the maxillofacial region. These results agree with the study by Wolff et al. (2016), who analyzed the exams of 253 patients who had undergone PR and CBCT to observe if additional 3D information had a significant impact on the surgical indication decision process. The authors concluded that CBCT provides important additional data for surgical planning, such as lesion borders, lesion size, and lesion relationship with adjacent anatomical structures. However, the surgical indications were not significantly influenced by the 3D image.

Also, Lim et al. (2018) analyzed 31 PR and CBCT exams to determine whether there are differences in the accuracy of differential diagnoses provided by oral and maxillofacial radiologists and their confidence when using either modality concluding that although there were differences between PAN and CBCT with respect to some lesion features, CBCT did not improve diagnostic accuracy. Our study showed that CBCT did not change the indication of the treatment type, but it was important for the surgical planning.

The main limitations of this study are related to the sample size, with 32 cases, in addition to the assumptions regarding diagnostic studies, which require a systematic and reproducible methodology. Most of the studies in the literature address a specific group of lesions and case reports. The published research has sample sizes similar to ours (Lim et al., 2018; Pittayapat et al., 2014; van den Brekel et al., 1998) and possibly had the same difficulties in obtaining a complete file or excellent images to perform the analysis. This can be an issue meriting warning clinicians about the need for a better health care records policy. Although small, the sample was carefully chosen. Furthermore, as a comparative study of two different imaging modalities (PR and CBCT), all the selected cases of our sample should be composed by both exams with an adequate imaging quality. In the past, many maxillofacial surgeons usually prescribed only panoramic radiography as a complementary diagnostic examination. In recent years, an increasing use of only CBCT for bone lesions evaluation should be noted. Further studies with a larger sample should be done in order to predict better indications for CBCT in oral surgery.

Although there is abundant research associated with CBCT, there is a lack of evidence about its impact on treatment decisions. Further studies are needed to show the possible benefits of using CBCT compared with conventional exams in order to establish the treatment plan according to the correct indications, avoiding unnecessary exposure to radiation. CBCT can still be considered a recent technique and presents new challenges for imaging diagnosis. Its use in dentistry has grown faster than scientific evidence on its indications. Besides widespread criteria of image selection or prescription, other issues should always be considered, such as the impact on the final treatment and on the patient's quality of life, social effectiveness, and the advantage for the clinician's use. Finally, the decision to use surgical sectional exams should be taken together by the clinician and by the surgeon who will operate on the patient so that there is no unnecessary exposure, but at the same time, sufficient information is obtained.

5. Conclusion

CBCT increases the certainty of the professional in the evaluation of bone lesions of the maxillofacial region; however, it does not change the indication of the treatment type.

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Declaration of interest

None.

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Appendix A. Supplementary data

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