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REVIEW

Review on the applications of ultrasonography in dentomaxillofacial region

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Abstract

Use of ultrasonography (US) in dentomaxillofacial region became popular in recent years owing to increasing radiation dose concerns and economic limitations. It helps to visualize fine detail of the surface structure of the oral and maxillofacial tissues without ionizing radiation. In diagnostic ultrasound, high frequency sound waves are transmitted into the body by a transducer and echoes from tissue interface are detected and displayed on a screen. Sound waves are emitted *via* piezoelectric crystals from the ultrasound transducer. US technique can be used in dentomaxillofacial region for the examination of bone and superficial soft tissue, detection of major salivary gland lesions, temporomandibular joint imaging, assessment of fractures and vascular lesions, lymph node examination, measurement of the thickness of muscles and visualization of vessels of the neck. It has the potential to be used in the evaluation of periapical lesions and follow up of periapical bone healing. Also, it may be used for the evaluation of periodontal pocket depth and for the determination of gingival thickness before dental implantology.

Key words: Ultrasonography; Dentistry; Radiology; Dentomaxillofacial radiology

Core tip: Use of ultrasonography in dentomaxillofacial region became popular in recent years owing to increasing concerns regarding radiation dose and economic limitations. It provides several advantages for dentomaxillofacial imaging such as; presence of non-ionizing radiation, portability, possibility of dynamic and repeated examinations and low cost. Main drawbacks include limited penetration into bone and gas filled structures, less spatial resolution at deep tissues and lack of expertise.

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INTRODUCTION

Use of ultrasonography (US) in the dentomaxillofacial region became popular in recent years owing to increasing radiation dose concerns and economic limitations. Sound frequencies above those of audible limits (30 Hz to 20 KHz) are known as ultrasound[1]. In diagnostic US, high frequency sound waves are transmitted into the body by use of a transducer and echos from tissue interface are detected and displayed on a screen[2,3]. Sound waves are emitted *via* piezoelectric crystals from the ultrasound transducer. Piezoelectric crystals are constructed from material that changes electric signals to mechanical vibrations and vice versa[4,5]. The piezoelectric system is based on the principle that quartz is subject to a change in shape when placed within an electrical field[1,6]. The main component of the transducer is a thin piezoelectric crystal or material made up of a great number of dipoles - distorted molecules that have a positive charge on one end and a negative charge on the other - arranged in a geometric pattern. Currently the most widely used piezoelectric material is lead zirconate titanate[7].

Acoustic impedance is the term used to define the resistance of a material to propagation of ultrasound waves. It depends on the density of the material. If the material is solid, the particles are denser and sonographic waves are reflected more. Therefore, solid material transmits fewer sound waves than fluids and less ultrasound waves are reflected back from fluids. As a result, an echogenic "black" image is produced. Stones and bones reflect more sound waves than fluid and they produce "white" bright images. Since ultrasound waves cannot transmit through stones, a black acoustic shadow is present behind them. Air is a robust ultrasound beam reflector which makes it difficult to visualize structures[4].

Advantages of US

US provides several advantages for dento-maxillofacial imaging compared to other advanced imaging techniques such as: Absence of ionizing radiation, portability, possibility of dynamic and repeated examinations and low cost. US is well recognized in inflammatory soft tissue conditions of the head and neck region along with superficial tissue disorders[2,8]. US is also an alternative diagnostic method for the imaging of temporomandibular disorders owing to satisfactory and promising results obtained from high resolution US in the assessment of temporomandibular joint (TMJ). It is harmless, fast, comfortable, economic and available in most centers and those make US a good candidate for TMJ evaluation[9]. With the aid of resolution transducer, US can demonstrate the internal muscle structures clearer than computed tomography (CT). US can also be used for the evaluation of submandibular and sublingual salivary glands. Sialolithiasis of parotid gland appears as echo-dens spots with a characteristic acoustic shadow[2,10]. Color Doppler US is used to identify vasculatures and to assess blood flow velocity and vessel resistance together with the surrounding morphology[2]. Furthermore, US is the only available imaging technique that can be used for frequent routine follow-up of cervical lenf node metastases[11,12]. US guided core needle biopsy is recommended as a safe and reliable technique in the diagnosis of cervico-facial masses with a high diagnostic yield[13,14]. The application of US in midfacial injuries is most useful for the visualization of the zygomatic arch when immediate imaging is performed after closed reduction. US can be considered as the imaging of choice when there is a contraindication to CT or plain films (for example, in pregnant women and patients with cervical spine injuries)[15,16]. When a trauma occurs, US can be used to investigate potential fracture lines of the injured bone through a real time examination[17].

US images can be used to assess the size, content and vascular supply, and provide a provisional diagnosis that may differentiate cysts and granulomas. An X-ray image may show a lesion more accurate than ultrasound. However, it is not possible to figure out the pathological nature of the lesion with the X-Ray whereas an ultrasound image can provide accurate information about the pathological nature of the lesion[17]. Using a non-invasive and non-ionizing radiation technique makes it possible for the clinician to evaluate soft and hard tissue healing after periodontal surgery. Also, US may be used for the clinical assessment and treatment planning prior to implant placement[18].

Disadvantages of US

US waves can damage tissues at high exposure levels, in addition to having teratogenic effects, due to heat, and acoustic cavitation. However, within the diagnostic range at low intensities and pressure levels, occurence of heating beyond the normal physiological range has very low probability[19]. In addition, metallic implants, dental fillings and restorations may cause blurring of the image due to artefacts generated by the metal[20].

It is difficult to visualize the articular disk with US when it is placed between two hard tissue structures. Therefore, imaging disk position by using US is difficult and may be problematic[21]. US is also unable to detect minimal and/or non-displaced fractures. In addition, it is not possible to delineate complex multiple facial fractures and to distinguish new fractures from old ones. Identification of intracapsular fracture of mandibular condyle due to overlapping of zygomatic arch may be impossible. Finally, in the case of acute conditions with facial edema and empyema bone visualization may be complicated[16,22].

Table 1 Diagnosis of fractures with ultrasonography

Ref.	Design	Sample size	Fracture	Method	Accuracy
Nemati S *et al*[28]	Single blind	37	Nasal bone	Physical exam	100%
Atighechi *et al*[29]	Prospective	128	Nasal bone	Physical exam	84%
Ogunmuyiwa *et al*[30]	Prospective	21	Zygomaticomaxillary	CT	100% zygomaticarch 90% infraorbital 25% frontozygomatic
Mohammadi *et al*[31]	Retrospective	70	Nasal bone	Physical exam	97%
Javadrashid *et al*[32]	Cross-sectional	40	Nasal bone	CT	94.90%
Lee *et al*[33]	Cross-sectional	140	Nasal bone	CT	100%
Blessmann *et al*[27]	Cross-sectional	10	Midfacial	CT	Undisplaced zygoma
Jank *et al*[34]	Prospective	13	Orbital	CT	92% medial wall 88% lateral wall
Jank *et al*[35]	Prospective	40	Orbital	CT	88% medial wall 90% lateral wall 97% infraorbital
Jank *et al*[36]	Prospective	58	Orbital	CT	96% orbital floor

CT: Computed tomography.

Application of US in dentomaxillofacial region

In general terms, US can be utilizied for the assessment of maxillofacial region fractures, temporomandibular joint disorders, cervical lymphadenopathy, swelling in the orofacial region, and salivary gland pathology[14]. Besides, periodontal US is a non-invasive diagnostic method for measuring pocket depth which is an indicator of periodontal health[6].

MIDFACIAL FRACTURES

There are several studies which were conducted in order to assess the versatality of US for midfacial fracture diagnosis in trauma cases. Authors of a study used ultrasound in diagnosing zygomatico-orbital complex fractures and found an accuracy of 94%[23]. McCann *et al*[24] found lower accuracy (85%) in diagnosing fractures of the zygomatico-orbital complex when compared to aforementioned study. Another study, reported 86% accuracy in diagnosing fractures of the orbital floor[20]. Gülicher *et al*[25] showed that ultrasonographic control of fracture repair led to excellent results in almost all patients. Visualization of different types of midfacial fractures was assessed by Friedrich *et al*[16] using ultrasound imaging. Types of fractures evaluated were orbito-zygomatical complex fractures, isolated fractures of the zygomatic arch, orbital floor, nasal bone, frontal sinus, along with complex Le-Fort fractures. The application of ultrasound in midfacial fractures was found to be most useful for the visualization of the anterior wall of the frontal sinüs and zygomatic arch. However, it was difficult to detect non dislocated fracture[26]. According to Blessmann *et al*[27] by using US, zygomatic arch could be visualized quite reliably whereas assessment of the orbital floor proved to be rather difficult. Soft tissue covering of the tissues impairs imaging of fractures in several planes. Therefore, the application of US is not a substitute for accurately taken X-ray imaging for detecting fractures of the mandibular ramus and condyle[16].

We may conclude that most reliable diagnosis with the use of US in traumatic cases is achieved in zgomatico-orbital complex and anterior frontal sinus wall fractures. Table 1 shows different literatures and their accuracy values regarding diagnostic ability of US for fracture diagnosis.

Temporomandibular disorders

US, an alternative technique to magnetic resonance imaging (MRI), was utilized for assessing TMJ in the beginning of 1990´s. The imaging procedure includes transverse and longitudinal scans, thereby; the antereriosuperior joint compartment can be examined in axial, coronal, and oblique views. The condyle and glenoid fossa are generally hyperechoic, whereas; connective and muscular tissues are isoechoic and they appear heterogeneously grey. However, surface of the joint capsule, highly reflects the sound waves, thus generating a hyperechoic line. Superior and inferior joint spaces are seen as hypoechoic[21]. When the condyle translates from closed mouth position to open mouth position operator should constantly adjust the position of the transducer during imaging, for better visibility of the disc[37]. Emshoff *et al*[38] found high specificity values at the closed mouth (1.00), half mouth opening (0.94), and maximum mouth opening (0.95) positions. Thus, they concluded that US was a reliable diagnostic tool in diagnosing normal disc position at the various mouth opening positions. A meta-analysis of US for the detection of TMJ anterior disc displacement revealed that high resolution US was superior in the diagnosis of anterior disc displacement without reduction[39]. On the other hand, utilization of US for detecting lateral and posterior displacements was not suggested. Overall, the diagnostic efficacy of US in TMJ evaluation is acceptable and can be used as a rapid preliminary diagnostic method[40]. Table 2 compares several studies which utilizied US for the assessment of TMJ.

Muscle disorders

On US imaging, temporalis muscle is seen as a thin

Table 2 Comparision of ultrasonography studies for the assessment of temporomandibular joint

Ref.	Sample size	Method	Accuracy
Razek *et al*[44]	40	MRI	77.5% anterior displacement 66.7% sideway displacement
Bas *et al*[45]	182	Clinical diagnosis	71%
Byahatti *et al*[46]	400	Clinical diagnosis	76%
Cakir-Ozkan *et al*[9]	56	MRI	68%
Landes *et al*[47]	68	MRI	64% 2 dimensional 69% 3 dimensional
Landes *et al*[48]	272	MRI	70%
Tognini *et al*[49]	82	MRI	73.10%
Jank *et al*[50]	200 (high resolution US)	MRI	Disk displacement 92% closemouth; 90% openmouth
Emshoff R *et al*[51]	96	MRI	Disk displacement without reduction 93%
Uysal *et al*[52]	64	MRI	Internal derangement 100%
Emshoff *et al*[53]	128	MRI	Internal derangement 95% Disk displacement without reduction 90% Disk displacement with reduction 92%

MRI: Magnetic resonance ımaging; US: Ultrasonography.

hypoechogenic band lying adjacent to the medial part of the temporalis fossa. The bony landmark is identified as a hyperdense line, whereas the course of the temporalis muscle is best visualized by having the patient clench. The masseter muscle is seen as a homogeneous structure lying adjacent to the echogenic band of the mandible. The anterior digastric muscle corresponds to round hypoechogenic zones located lateral to the respective mylohyoid muscles. The posterior digastric muscle is seen as a hypoechogenic band located under the homogeneous ultrasonographic pattern of the parotid gland. Sternocleidomastoid muscle is easily visualized due to its large size and typical band shape which shows a solid hypoechogenic ultrasonographic pattern. The medial boundary of the sternocleidomastoid muscle is identified as a very dense hyperechogenic line[41]. US was found to be useful for the measurement of masseter muscle thickness[41]. In the inflammatory muscle, the echogenic bands, which correspond to the internal fascia or tendon of the muscle, are frequently diminished or disappeared. Muscle with histologically verified edema shows less echogenity compared to that of muscle without edema[42]. In view of the importance of preoperative assessment of the hyomental distance ratio in predicting difficult incubation and laryngoscopy procedures, authors assessed the feasibility of measuring the hyomental distance ratio as well as volumes of the tongue and muscles of the floor of the mouth in obese patients using submandibular sonography[43].

Soft tissue masses of the neck

Thyroglossal cysts and branchial cleft cysts are mostly encountered cervical cysts. Less frequently, cystic hygomas, dysontogenetic cysts, ranulas and laryngoceles are found. On US examination, thyroglossal cysts most often appear anechoic with posterior acoustic enhancement. Debris in cervical cysts can result in a hypoechoic, pseudosolid appearance. Although most of branchial cleft cysts are hypoechoic some of them are anechoic. Epidermoid and dermoid cysts are usually located in the midline of the floor of the mouth or the tongue. Ultrasonographically ranulas are smoothly marginated, anechoic or homogeneously hypoechoic lesions without internal color or power Doppler signals[54]. Palagatti *et al*[55] found a diagnostic accuracy of 92.2% for US in the diagnosis of cystic lesions which is in line with the previous literature.

Inflammation

Acute inflammation causes swelling with loss of the normal glandular homogeneous bright echotexture. US is able to show hyperreflective microbubbles of gas in supurative sialadenitis with adjacent reactive nodes[56].

A study[57], found that most of the inflammatory swellings had relatively clear boundaries, hypoechoic intensity and homogeneous ultrasound architecture of lesions. Considering inflammatory swellings, US had a sensitivity of 97% and specificity of 100%, whereas; clinical diagnosis had a sensitivity and specificity of 85.7%[57]. As can be seen, US was found to have high sensitivity in the diagnosis of inflammatory swellings of the head and neck region.

Bone lesions

Odontogenic tumor is hyperechogenic because of the uniformity of the tumor mass. Odontogenic cystic lesions are unechogenic, because of their liquid content. Keratocystic odontogenic tumors are hypoechogenic, because of their dense and thick content[8].

Salivary gland tumors

The most common benign salivary gland tumors are adenolymphoma, pleomorphic adenoma, basal cell adenoma, myoepithelioma and papillary cystadenoma. The most common malignant salivary gland tumors are mucoepidermoid carcinoma, adenoid cystic carcinoma, acinic cell carsinoma and adenocarcinoma[58]. The intra-

Table 3 Studies assessing salivary gland tumors by use of ultrasonography

Ref.	Design	Sample size	Method	Accurancy
Song HI *et al*[64]		228 US (CNB)	Histology	88.20%
		371 FNAC		58.20%
Davachi *et al*[61]	Cross-sectional	22	MR	95%
Higashino *et al*[65]	Prospective	154	Histopathology	89%
Freed[66]	Retrospective	35	CT	89%
Pfeiffer J *et al*[67]	Prospective	161 (CNB)	Histopathology	94%
Wu *et al*[68]	Retrospective	189	Histopathology(benign malign differentiate)	38.90%
El-Khateeb *et al*[69]	Prospective	44	Histopathology (grey scala US-tumor border)	84%
			CD US vasculartumor	81%
			SPD malignant tumor	81%
Huang *et al*[70]	Retrospective	64 (CNB)	Histopathology	94.10%
		107 (FNA)		55.60%
Kraft *et al*[71]	Retrospective	104 (FNA)	Histopathology	99%
Bozzato *et al*[72]	Cross-sectional	125	Histopathology	92.80%

US: Ultrasonography; MR: Magnetic resonance; CT: Computed tomography; CNB: Core needle biopsy; FNA: Fine needle aspiration; FNAC: Fine needle aspiration cytology; CD: Color doppler; SPD: Spectral doppler.

glandular mass lesions are hypoechoic when compared with surrounding homogeneous echogenicity of the normal gland parenchyma. Benign lesions tend to be small, well defined and not associated with enlarged cervical nodes, whereas malignant lesions are usually irregular and have heterogeneous internal structure[59]. Malignant nodes are recognized by round shape, heterogeneity, loss of hilar architecture, abnormal, disorganized vascularity, cystic change and extracapsular spread[60]. Liu *et al*[58] compared US, computed tomography and magnetic resonance imaging for the clinical differential diagnosis of patients with salivary gland tumors. The specificity of US is generally good due to the fact that the majority of salivary gland tumors are benign. For some cases, such as a large mass in a deep lobe of salivary gland, differential diagnosis is difficult with US. Another cros-sectional study showed that US was unable to accurately display invasion to deeper adjacent anatomic structures in patients with salivary gland tumors[61]. Li *et al*[62] evaluated forty eight patients with acinic cell carsinoma of the parotid gland who underwent preoperative US and CT. US features of most acinic cell carsinomas were almost consistent with the CT features in terms of border echo texture and density on contrast scans. However, in consideration to shape there was a difference. Their shapes were irregular on the US and regular on CT images. Ishii *et al*[63] retrospectively compared US and histologic evaluation of surgical specimens of palatal tumors. US was shown to be a useful technique for the preoperative evaluation of patients with small palatal tumors which were less than 3 cm in diameter. Table 3 shows comparison of different studies conducted in order to assess salivary gland tumors with US.

Sjögren syndrome

Primary Sjögren's syndrome (PSS) is a chronic autoimmune condition affecting the exocrine glands. Studies indicate that US findings have a high specificity for PSS. Authors observed relations between US findings and severity of dryness symptoms, exocrine function glandular inflammation and systemic autoantibodies. Authors suggested that US is an effective tool for assessing salivary gland involvement in PSS[73]. Obinata *et al*[74] compared sialography, histopathology and US for the diagnosis of Sjögren syndrome. The sensitivity was 83.3% for sialography, 77.8% for US, and 63.9% for histopathology[74].

Salivary gland calculus

The first use of ultrasound to identify and locate a parotid calculus was reported by Pickrell in 1978. Transcutaneous extra-oral ultrasound has been introduced as a simple and safe imaging technique for the detection of calculi in the salivary glands. It was found to be as effective as sialography in identifying calculi of 2 mm in diameter. Contemporary innovative small high frequency ultrasound probes allow access to the ducts both in the submandibular and parotid glands *via* an intraoral approach[75].

Oral cancer tumor thickness

Wakasugi-Sato *et al*[76] developed a method in order to allow operators to easily assess and confirm the surgical clearance of tongue carcinomas intraoperatively using intraoral US. Tumor thickness was reported as an important prognostic factor in cancers of the oral cavity. Authors demonstrated that there was a strong correlation between tumor thickness measured from ultrasonic images and histological sections[77]. Similarly, Yuen *et al*[78] evaluated the correlation between ultrasonic and pathologic tumor thickness. They found a statistically significant correlation between pathologic and ultrasonic thickness. Shintani *et al*[79] measured tumor thickness of squamous cell carcinoma and compared the clinical usefulness of CT, MRI, and intraoral US to delineate the extent of tumors. They showed that intraoral US is very accurate and valuable for mapping these tumors. Yesuratnam *et al*[80] compared preoperative tumor thickness on high resolution intraoral US and MR imaging with histologically determined tumor thickness. They found high correlation between tumor thickness on preoperative US and histological primary tumor thickness and good correlation between MRI and histological primary tumor thickness. In conclusion, US could be used as the primary imaging modality for the assessment of tongue tumor thickness as it improved planning for prophylactic neck dissection in early stage disease.

Lymph nodes

In lymphadenitis, the lymph nodes are enlarged (axial diameter measures more than 10 mm) with an ovoid to round shape. Nonspecific inflammatory lymph nodes are usually sharply bordered and the hilum is rarely visible. The ultrasonographic features of metastatic lymph nodes that can be depicted are increased size, a rounder shape, and heterogeneity caused by tumor necrosis, keratinization or cystic degeneration inside the tumor. Generally, round shape is considered to be more suspicious than an oval or flat shape. The size criteria may vary between 5 and 30 mm[81]. The lymph node status is one of the most important predictors of poor prognosis in head and neck tumors and it is important for the treatment plan. De Bondt *et al*[81] performed a meta-analysis of the detection of lymph node metastases by comparing US, US guided fine needle aspiration cytology, computed tomography and magnetic resonance imagining in patients with head and neck cancer. In conclusion, US guided fine needle aspiration cytology was found to be the most reliable imaging technique to assess the presence of metastases in cervical lymph nodes in patients with head and neck cancer. Authors of another study conducted US on 18 patients with stage 1 and stage 2 squamous cell carcinoma of the tongue. They evaluated the histolopathological metastatic nodes. The sensitivity in the detection of smaller metastatic nodes for US (58%) was lower than that of CT (83%)[82].

Implantology

US may play an important role in locating submerged implants. The authors reported that a new ultrasonic device including a soft tissue matched transducer with a customized transreceiver and signal processing was capable of measuring soft tissue thickness over bone and implants placed in porcine models. The authors also suggested that this new ultrasound device was efficient as a diagnostic tool for intraoral measurements of the inferior alveolar canal and floor of the maxillary sinus before dental implant placement[19]. Authors measured the distance from the bottom of the osteotome to the inferior canal and maxillary sinus floor using a novel ultrasonic device and conventional radiographs. A significant positive correlation was observed between the radiographic and US measurements. US has the potential to be an alternative diagnostic tool for implant dentistry owing to its nonionizing nature[83].

Periodontal US

US has emerged as a noninvasive periodontal assessment tool that yields real time information regarding clinical features such as pocket depth, attachment level, tissue thickness, histological change, calculus and bone morphology as well as tooth structure for fracture cracks[6]. Authors designed a specific intraoral probe for dental use. Because of the small size of the probe and its special design, patients felt that the oral US was a stress free, painless and fast examination tool. The periodontal width was directly accessible and measurable. Besides, it offered new prospects for gum thickness evaluation, earlier detection of a small anatomic change, and diagnosis of oral mucosa lesions. Further studies are essential before intraoral US is accepted for routine clinical use in dentistry[84]. Xiang *et al*[85] used US for the assessment of a periradicular lesion of endodontic origin. Authors obtained information regarding the size and vascular supply of the lesion. They suggested that US may be used for differential diagnosis of periradicular lesions by identifying the contents of lesions and their vascularization. Gundappa *et al*[86] showed that there was a definite correlation between the echostructure of the periapical lesions and histopathological features. They suggested ultrasound real time imaging as a reliable diagnostic technique for differentiating periapical lesions. US was found to be a simple, quick, non invasive and standardized method for measuring the thickness of the palatal gingiva. US device was able to determine the palatal gingival thickness atraumatically and painlessly in contrast to the conventional methods of transgingival probing witch is an invasive method and may give false measurements because of the tissue edema which occur due to injection of local anesthesia prior to the procedure[87].

Foreign bodies

Another possible application of US studied is the visualization of foreign bodies in soft tissues. Among other imaging modalities, the best sensitivity and specificity results were achieved by using US with the advantage of visualization of the size and form of well-shaped materials such as wood, composite, amalgam and glass[88].

Doppler US

Doppler US has found wide spread use in the assessment of peripheral vascular disease. Authors evaluated Doppler US in the assessment of congenital vascular lesions of the maxillofacial region. Doppler US can be used to characterize the flow of head and neck vascular anomalies and to differentiate hemangiomas from other vascular malformations which is crucial in treatment planning[89]. It was also shown that ultrasound with color Doppler US was an effective tool in monitoring the healing of periapical lesions after surgery[90]. Baladi utlizied US to identify factors associated with alterations of mental artery flow. Intraoral B-mode Doppler US was used to assess mental artery flow and mental artery pulse strength[91]. Martins *et al*[92] by use of a Doppler US examined 65 patients who had submucosal and subcutaneous nodules. They found that US was an effective tool in the definitive diagnosis of nonspecific nodular lesions of the soft tissues located in the oral and maxillofacial region. Another study evaluated the efficacy of MRI and color doppler US in the diagnosis and differentiation of benign and malignant salivary gland tumors. Accuracy of Color doppler US was found to be 95% in determining tumor site[61].

CONCLUSION

As a conclusion, US is an innovative and evolving imaging technology with plenty of research continuing to be done in medical field. It is safe, rapid, portable and economic. Further studies towards clinical applications of the US in the dento-maxillofacial region are essential in order to obtain information regarding accurate and appropriate clinical usage of the system in dentistry[93].

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