STRUČNI RAD (PROFESSIONAL PAPER)

Diagnostic imaging of sialolithiasis

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Abstract

The existence of possible pathological conditions of the salivary glands requires the use of certain imaging techniques, which contributes to a better diagnosis of the disorder and proper treatment. Stones, inflammatory processes and tumors are conditions that are accompanied by unpleasant symptoms inside the oral cavity. Sialolithiasis is the presence of stones in the salivary glands and is a common pathological disorder. The aim of this paper is to present the diagnostic imaging of sialolithiasis. That includes the methods of dental radiography and different methods of sialography. Conventional imaging techniques in dental radiography have been abandoned over time. USG and sialography methods are more often used in clinical practice nowadays. Sialographic methods include the application of a contrast medium, which results in a better visualization of the excretory ducts of the salivary glands, in both conventional and digital imaging. CT and MRI sialography methods visualize smaller stones better in the salivary excretory ducts, with some limitations. The results of the recently reviewed scientific researches show that the radiographic imaging methods for sialolithiasis are complementary. Sialography and USG are the initial methods in diagnosing sialolithiasis, but the use of CT and MR can provide valuable additional diagnostic information.

Key words: dental radiography; sialography; stone; sialolithiasis; glands; salivary glands; Wharton's duct

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Introduction

Salivary glands are exocrine glands responsible for secreting saliva. We can distinguish small (buccal, labial, palatal, lingual) from three pairs of large salivary glands – parotid, submandibular and sublingual [1]. The parotid (Stensen's) duct starts opposite the second molar of the lower jaw, the submandibular (Wharton's) duct ends at the *frenulum* of the tongue, and the sublingual (Rivinius) ducts are located in the submucosus floor of the oral cavity [2]. There are multiple roles of the salivary glands in the mouth. They are essential for: moisturizing, lubricating and cleaning the mucous membrane of the oral cavity, decomposition of carbohydrates and lipids, excretion of protective substances (IgA, enzymes, proteins) and also have a taste function (Figure 1) [1].

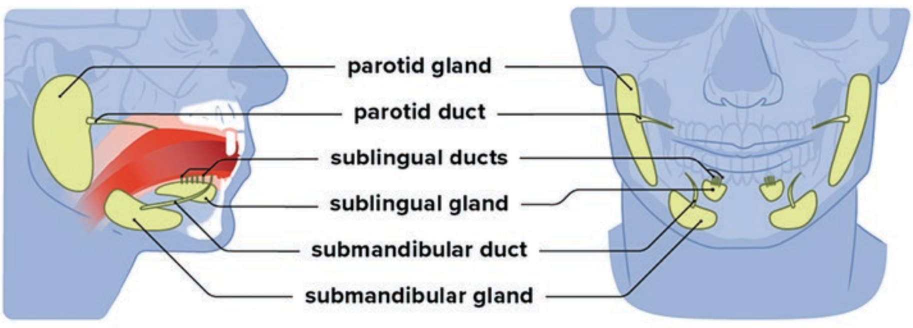

Figure 1. Anatomical view of salivary glands and excretory ducts
Source: https://www.medicalnewstoday.com/articles/322439#types

The most common pathological conditions that affect the salivary glands are stones (calcifications, concretions, sialoliths), inflammatory processes and tumors. Most mineral stones appear in Wharton's duct (85%) and there are several classified pathological conditions in which they are found [2]. The most common reason for the formation of stones is the anatomical position of Wharton's duct, where saliva accumulates. Also, because of more calcium and phosphate, saliva is viscous [1]. Stones have a crystalline structure and are composed of calcium phosphate, carbon, magnesium, potassium chloride and ammonia [1]. The presence of stones in the salivary glands is known as sialolithiasis [1]. When salivary gland disorders occur, patients experience symptoms such as dry mouth, dysphagia and duct blockage, inflammation, serious dental caries and swelling [3].

Depending on the pathology, certain radiographic imaging methods are used, often complementary. These are: conventional radiography, sialography, scintigraphy, ultrasound (USG), CT (Computed Tomography), CBCT (Cone Beam Computed Tomography) and MRI (Magnetic Resonance Imaging). Conventional radiography, sialography, USG, CT, CBCT and MRI are used to show stones [1,4]. Sialography and scintigraphy are used to show inflammatory or tumor disorders. USG, CT and MRI are used to evaluate formations in the salivary glands [4].

Methodology

Intraoral occlusal images of the lower jaw

An intraoral occlusal radiogram enables an axial projection of the lower jaw, which is important for localization of stones in the salivary gland ducts [5]. An x-ray film used for this image has been replaced with a phosphor plate/ digital sensor. The image receptor was inserted into the mouth horizontally on the upper surface of the tongue and partly on the biting surface of the lower teeth, then pushed towards the *ramus* of the mandible as far as individual anatomical relationships allow and immobilized by a light bite of the patient. The radiation beam was directed cranially and have passed through the lower jaw and sublingual area. The radiograph represented mandible with the dental arch (only the crown teeth are visible) and the sublingual area [6] (Figure 2). The long axis of the tooth and the long axis of the receptor created a certain angle that must have cut in half in order to focus the X-ray beam on it. By directing the x-rays vertically through that angle, the direction of the x-ray beam was determined. In this way, the teeth region is shown distorted and reduced (Figure 3). In the occlusal technique, an X-ray tube with a round tube was used [5,6]. The position of the receptor could vary, depending on which part of the lower jaw should have displayed. A horizontal position was required to display the front part of the mandible with a horizontal angle of the central beam of 55-60°. To display the greater part of the mandible, the central beam was directed vertically with a horizontal angle of 90° and formed a true intraoral occlusal image of the mandible. If the position of the receptor was lateral, the central beam was angled 50° through the area of molars or premolars [7].

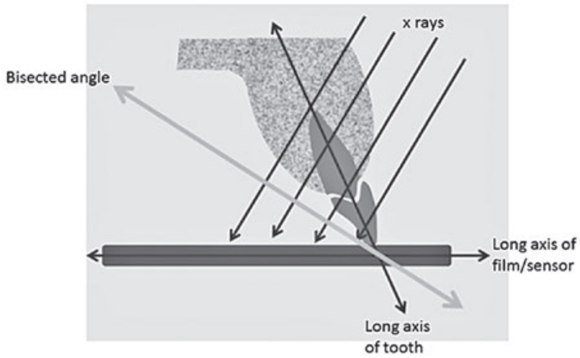

Figure 3. Formation of occlusal radiogram
Source: https://oralradiology.wordpress.com/2012/09/26/radiographic-technique-maxillary-occlusal-radiographs/

Intraoral digital images

With the transition to digital radiography, CCD (Charge-Coupled device) and CMOS (Complementary Metal Oxide Semiconductor) sensors were put into use. Performing an intraoral occlusal scan of the lower jaw with a digital sensor is not as simple as it was in the case of obtaining a standard scan using an X-ray film. An alternative method of recording with a digital sensor would be to attach the

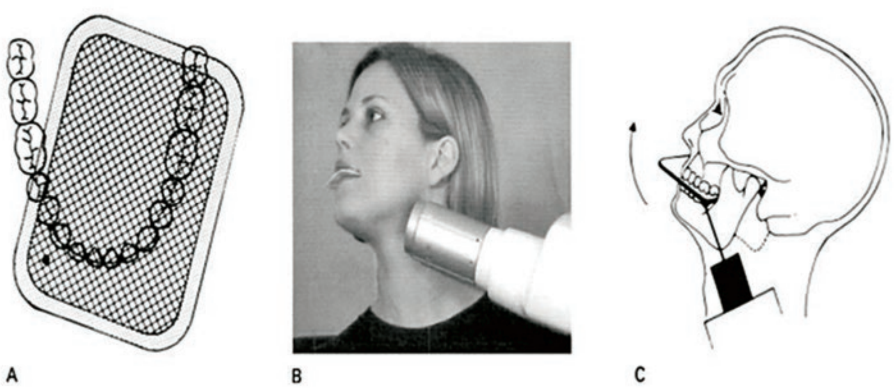

Figure 2. A) Position of the left lower jaw on the film; B) Positioning for the left occlusal lateral view; C) Lateral view includes a raised chin and tilted head of the patient
Source: https://codental.uobaghdad.edu.iq/wpcontent/uploads/sites/14/2021/01/2_5188546426027641343.pdf

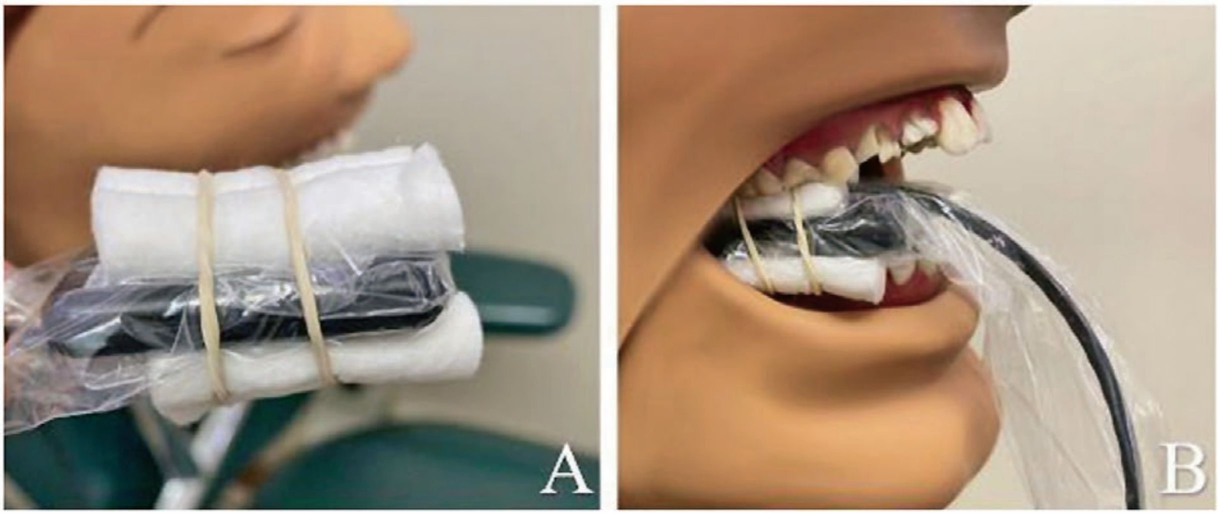

Figure 4. Placement of the intraoral digital sensor for imaging the salivary glands
Source: https://journals.assaf.org.za/index.php/sadj/article/view/12644/17586

sensor with two disposable cotton balls at the top and bottom held in place with an elastic band. The exposed side of the digital sensor is placed against the jaw segment in the area of interest (Figure 4) [8].

Orthopanthomography

The standard positioning and posture of the patient on the device for orthopantomography is the same for displaying the sialolithiasis. The patient should stand straight and perpendicular to the surface, which is checked with an imaginary line of the intraortibal rim and the external auditory canal (Frankfurt line) [5]. The head is positioned on the chin rest and is held laterally by holders. The patient should bite the intraoral bite template and place the tongue on the upper palate in order to display the teeth as correctly as possible [2].

Conventional and digital subtraction sialography

The patient is lying down on the imaging table. 2-3 minutes before the sialography, the patient can be given a sialogogue (a substance that causes immediate strong salivation), for example lemon, which makes the opening of the Wharton`s duct more accurate and an easier insertion of the catheter is possible [9]. Catheters and catheter dilators differ in size and from placing in Wharton's or Stensen's duct [9,10]. Immediately before catheterization and duct dilatation, it is recommended to perform local anesthesia with a specific anesthetic. A water-soluble contrast medium is manually injected to the level of pain or significant distension of the gland duct, which is an indication that the contrast agent has filled the parenchyma of the salivary gland. 1-1.5 ml of contrast medium is used to visualize the parotid gland or 0.5-1 ml to visualize the submandibular gland. Sometimes it is recommended to take an image after the application of the contrast medium, as it enables a dynamic evaluation of contrast evacuation from the duct of the salivary gland. Air must not enter the duct because it would imitate the appearance of stones. Radiographic images include two projections as standard. These are AP projection (submentovertical axial projection) and lateral projection. If necessary, oblique projections can be used [9].

When performing digital subtraction sialography, each sequential image should be preceded by a control image, without the addition of contrast medium, which is displayed as a "mask". Before changing the projection, the ducts should be decatheterized to ensure that the contrast medium does not settle in the ducts and falsify the results of the next series of images. The contrast medium is administered retrogradely after canalization and catheter insertion [9,11]. The advantage of this method is the removal of superposition produced by bony structures [9].

CBCT and CT sialography

The CBCT scan is performed exceptionally in clinical practice and the patient's positioning and posture on the device do not require a different procedure than usual. Depending on the position of the stone, the appropriate size of the imaging field and the appropriate side of the lower jaw are selected. The correct positioning of the patient is achieved with the help of laser beams [2,5].

CT sialography is a procedure that is very similar to classical sialography. Information about the stone can be obtained with the help of 3D visualization, multiplanar reconstruction and measurement of stone size [10].

MRI sialography

MRI sialography is an alternative method to digital subtraction sialography, for example in the case of impossibility of cannulating the opening of the salivary gland [11]. The examination is non-invasive, does not require cannulation of the opening of the salivary gland and does not expose patients to contrast administration or additional radiation. There are different methods of performing MRI sialography, but usually fast *spin echo* sequences are used – 2D/3D or single layer. T2 sequences (RARE, CISP, FISP) make the intraluminal fluid brighter and show the morphology of the excretory duct adequately without the use of contrast medium. Intravenous contrast medium can be useful addition during imaging [9,11].

Discussion

Comparison of intraoral occlusal imaging and orthopantomogram

An intraoral occlusal image of the lower jaw and an OPG (Orthopantomogram) were conventional radiographs in dental radiography that have been used to show sialolithiasis. Conventional radiographs are not sensitive enough to detect stones [13]. 80-90% of stones can be visible on a conventional radiograph, however, 20% of stones remain undetected due to their poor calcification [15]. Conventional radiographs including intraoral occlusal view of stones were the initial diagnostic choice in the past (Figure 5) [14].

Nel C. and the authors point out that the procedure for obtaining an occlusal radiograph was a simple procedure in the golden age of a film and photo stimulating phosphor plates. However, the process of obtaining an occlusal radiograph is a difficult process with more commonly used digital CCD or CMOS sensors [8]. Because of using digital sensors nowadays the process of obtaining occlusal radiographs is performed very rarely.

By searching the available literature recently, there is no available digital oclusal receptor on the market, so a standard intraoral digital receptor can be used for submandibular stones imaging. The receptor is placed occlusally with the application of mostly improvised experience techniques (Figure 6). These techniques can show the area of the Wharton's ducts, but not the areas of the parotid gland ducts. The need for occlusal imaging of salivary gland stones has been pushed out of everyday practice.

Orthopantomography has proven to be an useful method of diagnosing sialolithiasis and controling of treatment. OPG provides a good representation of the parotid gland but an anatomical structures can overlap with oval or elongated lesions [8,15]. Stones are seen on OPG as round, oval, cylindrical or irregular shaped lesions. Their size can be from 1-5.5 cm [16]. Soft tissue calcification can be seen in the perimandibular region (Figure 7).

Demidov and the authors determined the effectiveness of displaying sialolithiasis in the lower jaw on OPG images. They claim that the images have proven their effectiveness in diagnosing the presence of stones in the submandibular gland and Wharton`s duct [16]. However, the disadvantage of the images is that the stones can be superimposed with the anatomical structures of the lower jaw and their representation can be difficult (Figure 8). Also, certain calcifications can be replaced by stones and by an intraosseous lesions. Stones in the submandibular gland are usually displayed on the OPG if they are located in the back part of the excretory duct [15].

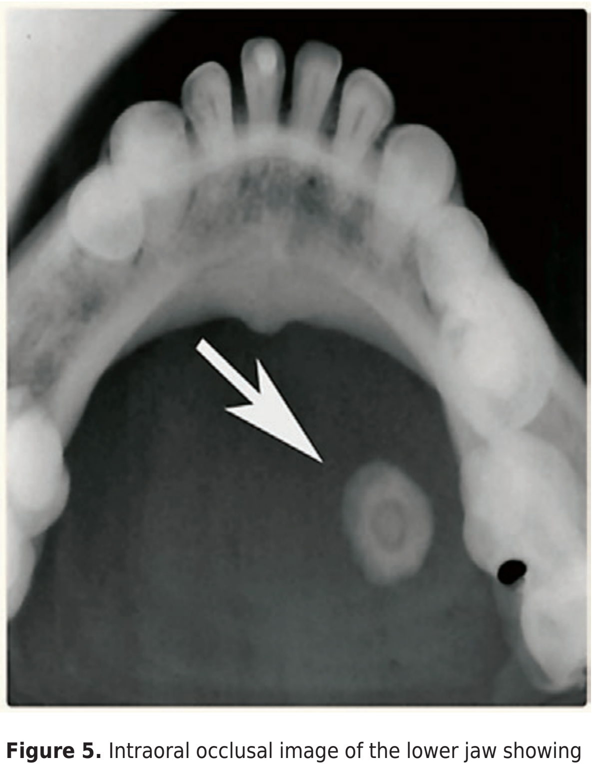

Figure 5. Intraoral occlusal image of the lower jaw showing a stone in the left Wharton's duct
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3389885/

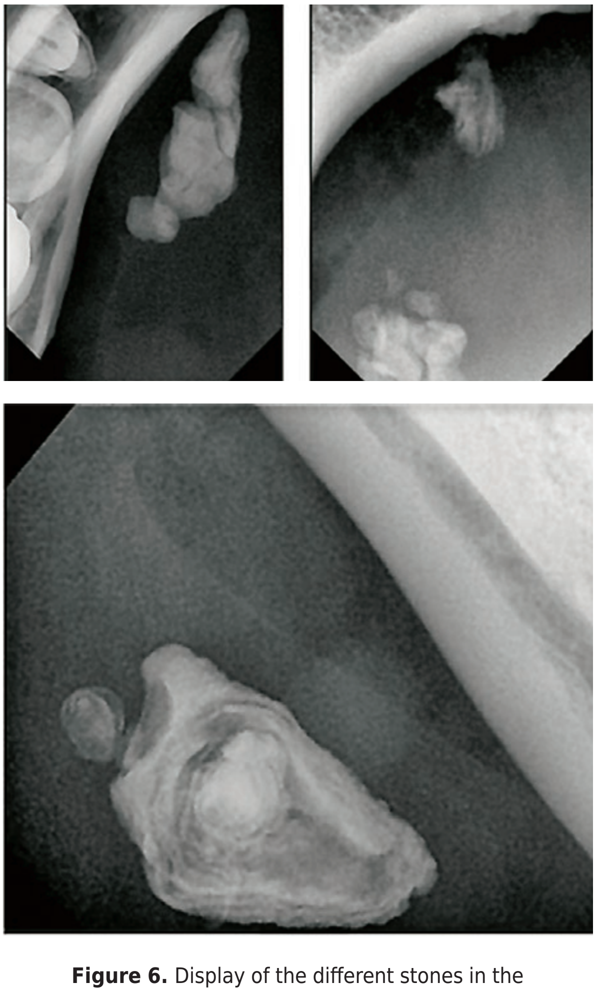

Figure 6. Display of the different stones in the lower jaw taken by an intraoral digital sensor -Vatech EzSensor, size 1.5
Source: authors

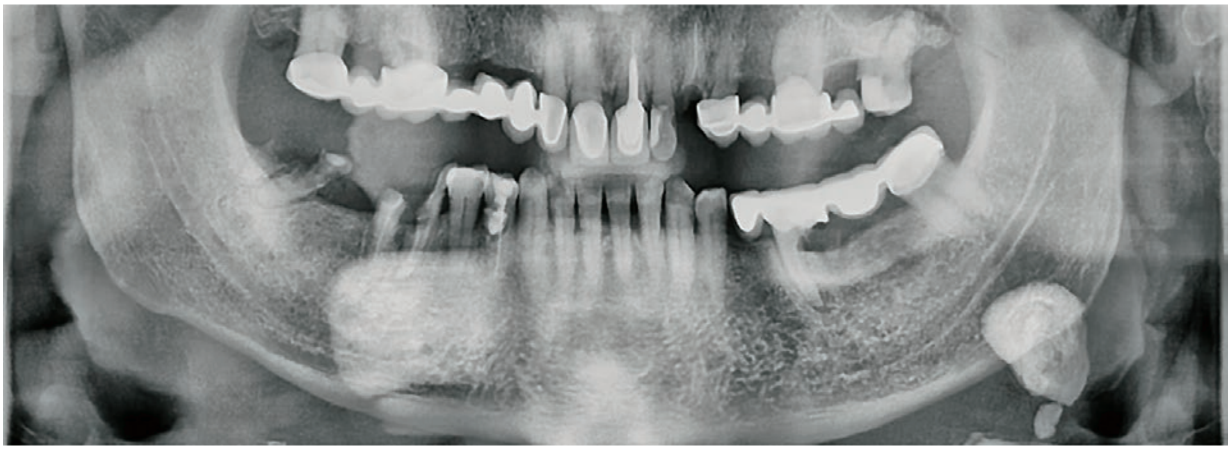

Figure 7. Display of a stone on the left side of the lower jaw on a cropped OPG (VATECH PaX-i3D Green machine)
Source: authors

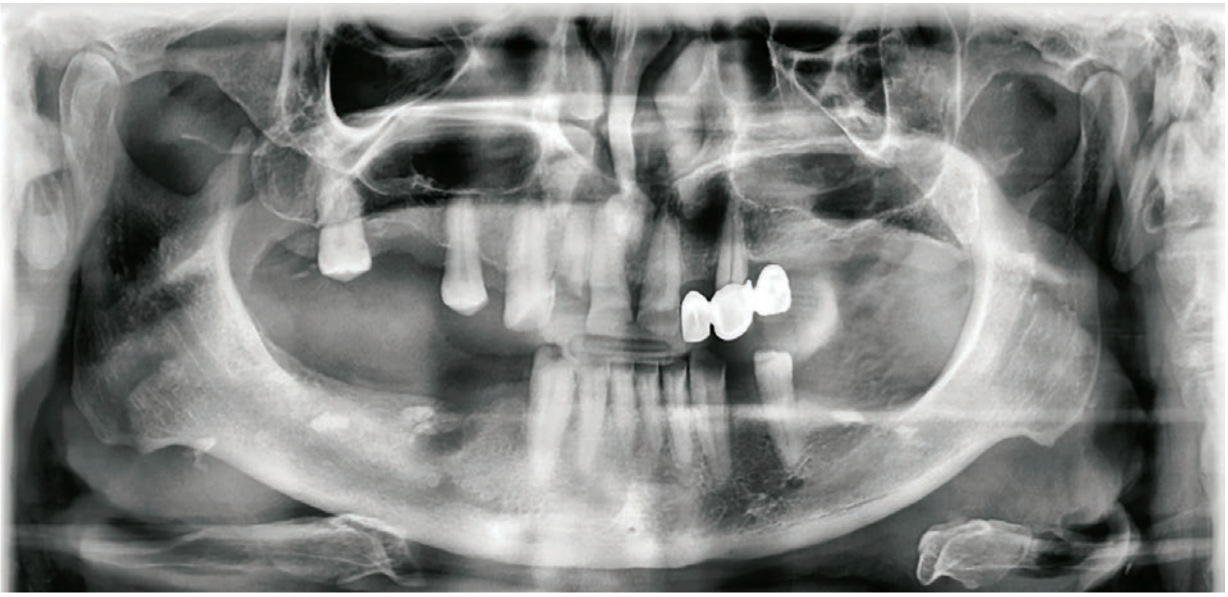

Figure 8. Display of superimposed stones in the right part of the lower jaw on the OPG (VATECH PaX-i3D Green machine)
Source: authors

Comparison of conventional and digital subtraction sialography

Conventional sialography, along with digital subtraction sialography, is a frequent diagnostic method where the presence of stones in the salivary gland is suspected. Depending on stone location in the parenchyma or gland`s duct, the right method of treatment is selected. The advantages of conventional sialography include a higher spatial resolution that allows excellent delineation of the main excretory duct and its branches, which ultimately helps to remove the stone forward to ease the obstruction of the duct [9,10]. Disadvantages of conventional sialography are a higher dose of radiation, the use of a contrast medium that can cause an allergic reaction, unsuccessful examination due to catheter placement or patient non-cooperation. Complications that can arise are local pain, perforation of the Wharton`s duct, and infections that need to be treated with antibiotics [10]. With digital subtraction sialography, unwanted consequences and complications are less, the procedure lasts 15-25 minutes and moderate sensitivity with slight edema of the salivary gland is felt for 24 hours [9].

Despite all the disadvantages, conventional and digital subtraction sialography are considered to be the best methods for visualizing the detailed anatomy of the excretory ducts of the salivary glands. The sensitivity of conventional sialography in the detection of stones ranges from 64-100%, and the specificity from 88-100%. Digital subtraction sialography has a sensitivity of 96-100% and a specificity of 88-91%. Sialography requires a lower dose of radiation than CT and is more affordable than MRI [9].

Reid and the authors showed the difference between conventional and digital subtraction sialography in the diagnosis of sialolithiasis on a series of cases. They state that sialolithiasis is not always visible with conventional sialography and that facial bones can cover the stone, especially if it is small. Digital subtraction sialography improves imaging sensitivity due to the subtraction process, where facial bones are visualized before the administration of contrast agent. In this way, more transparent stones can be displayed [17].

Comparison of USG, CBCT and CT/MRI sialography

USG examination of sialolithiasis is considered to be the first method of choice in diagnosis, according to some authors. It`s sensitivity is 94%, and specificity 100% [9]. Stones are often described as an echogenic, round or oval structures that produces an acoustic shadow, although those smaller than 2 mm may not produce an acoustic shadow. Stone detection might be mistaken for hyperechoic air bubbles mixed with saliva or the error might refer to very small stones in the intraparenchymal ducts. The detection of fine stones can be assisted by the addition of sialogogue, which causes dilation of the salivary ducts [9]. In addition to basic gray tones, Color Doppler or Power Doppler can be used [19]. Although dilatation of Wharton's duct is shown in 65% of cases, small stones are difficult to visualize. Finger pressure on the inside of the mouth can visualize stones near the opening of Wharton's duct or can be seen better in the medial part. Despite all the advantages, it has been shown that USG is less precise in differentiating a cluster of stones from a single large stone [9].

Terraz and the authors examined the reliability of USG for the determination of sialolithiasis. They claim that the USG image is not reliable enough to exclude small stones. Therefore, when sialolithiasis is suspected, they recommend other imaging techniques for the detection of small stones, such as conventional sialography or MRI sialography [18].

When a cluster of small stones does not differ from one large stone, it is recommended to do a CT sialography [9]. To determine the position, size and number of stones, millimeter-thin axial sections are used with multiplanar data collection with 3D reconstruction [20]. CT offers a high sensitivity of stones compared to USG (Figure 9). The contrast medium is particularly good at showing soft tissue, especially for parotid glandular masses. Furthermore, it enables evaluation of glands other than the parotid, visualization of glandular tissue and salivary ducts and better diagnosis of parenchymal pathology. The disadvantage is that it is an invasive procedure and patients are exposed to higher doses of radiation compared to conventional sialography [10]. CBCT imaging proved to be a valuable imaging method due to the higher spatial resolution of bone structures and lower radiation dose compared to conventional CT [9].

Miloglu and the authors conducted a study on the effectiveness of the visualization of salivary gland stones with the help of CBCT. Compared to conventional imaging techniques, they believe that CBCT was very sensitive in showing the location and size of stones. The advantage is that it creates images that are anatomically correct, and the dimensions of the stones are very reliable, which cannot be claimed for the calculation of the dimensions of the stones on the OPG, due to the presence of distortion factors and magnification factors. CBCT provides high sensitivity, reduced superimposition and reduced distortion of anatomical structures [21] (Figure 10). The main limitation of CBCT in diagnosing sialolithiasis is the lack of soft tissue windows compared to the CT device and the lack of additional information about, for example, narrowing or dilatation of Wharton's duct [17].

Dreiseidler and the authors claim that stones can be adequately visualized by CBCT and that the levels of diagnostic sensitivity and specificity are equal or higher than those obtained by other diagnostic methods, such as USG [22].

MRI sialography enables a precise morphological evaluation of the salivary gland ducts, enabling the visualization of distant branches, which was not possible on a CT modality. In MRI sialography, small stones that do not lead clogging of the salivary ducts can remain undetected, namely stones that are near the opening of the duct or in small intraglandular ducts [9]. The advantages of this method are fast acquisition, non-invasiveness and minimal possibility of replacing stones with air bubbles, since there is no need for insertion a catheter [10]. The limitation of MRI sialography is the lower spatial resolution (Figure 11), which makes it impossible to distinguish

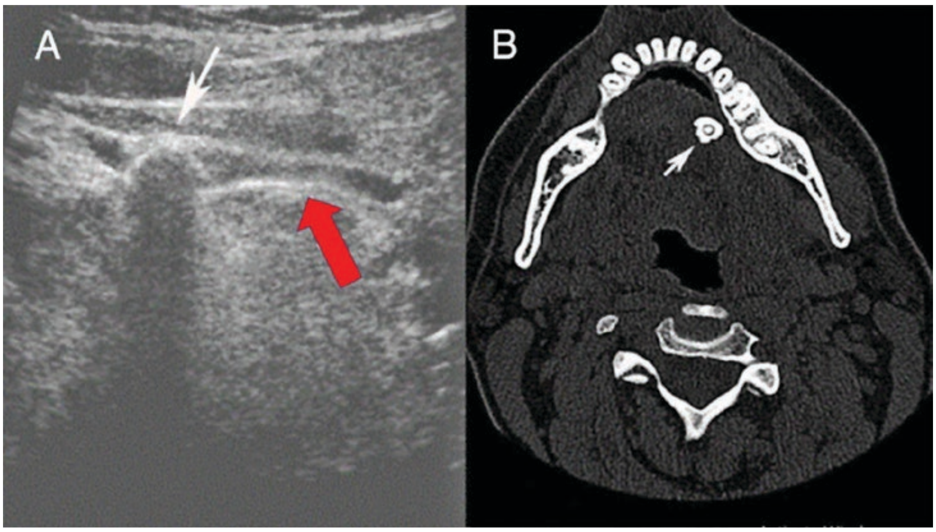

Figure 9. A) Display of stone and dilatation of the Wharton`s duct;
B) CT axial view of a stone in the left submandibular gland, size 1 cm
Source: https://ejo.springeropen.com/articles/10.1186/s43163-021-00165-y

Figure 10. A) Mandibular occlusal image of stone in the posterior left region; B) CBCT axial section of stone and mandible relationship; C) 3D reconstruction of stone; D) Transverse section of the stone position
Source: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0011-8516202000070001

between partial and complete occlusions of the gland ducts. MRI is considered a very effective method for imaging ducts of the major salivary glands [9].

Capaccio and the authors compared the visualization of salivary gland disorders on USG and MRI and they claim that small stones are better seen on MRI [23].

Becker et al evaluated the precision of MRI sialography in detecting salivary duct stones and stenosis by comparing USG with conventional sialography, and found that MRI sialography did not distinguish a stone from a dense mucosal part, and MIP (Maximal Intensity Projection) reconstruction can leave out the display of stones due to hyperintense saliva surrounding the stone [9].

Conclusion

Intraoral occlusal technique of imaging the lower jaw by an x-ray film, in order to detect the sialolithiasis, was a common radiographic practice in dental radiology. This imaging technique was abandoned with the transition to digital radiography and the use of intraoral digital sensors. However, due to the impractical feasibility of positioning the digital sensor and the difficulty of obtaining a high-quality visualisation of stones, imaging in this way is not common in clinical practice nowadays. Furthermore, stones may be visible on an OPG, but due to the overlapping of anatomical structures, stones might be covered in certain salivary gland ducts, which is not diagnostically acceptable, and due to the magnification and distortion factors, the dimensions of the stones are not completely reliable. Guidelines of stone visualization method vary globally, but conventional and digital subtraction sialography and USG are the usual initial choices. By injection of a contrast medium, excretory ducts are more accurate on the image. Although it is a non-invasive method and does not expose the patient to radiation, USG has the disadvantage that smaller stones are difficult to visualize. Compared to CT sialography, CBCT can provide useful information about the location and size of the stones, but it cannot provide additional information about the relationship between the stones and the surrounding soft tissue. CT and MRI, in general, allow a better visualisation of smaller stones. Their limitations include a higher dose of radiation, invasiveness and application of contrast medium on CT or lower spatial resolution on MRI. MRI sialography is still not considered as standard imaging method, but it is considered to be effective for the diagnosis of sialolithiasis. ■

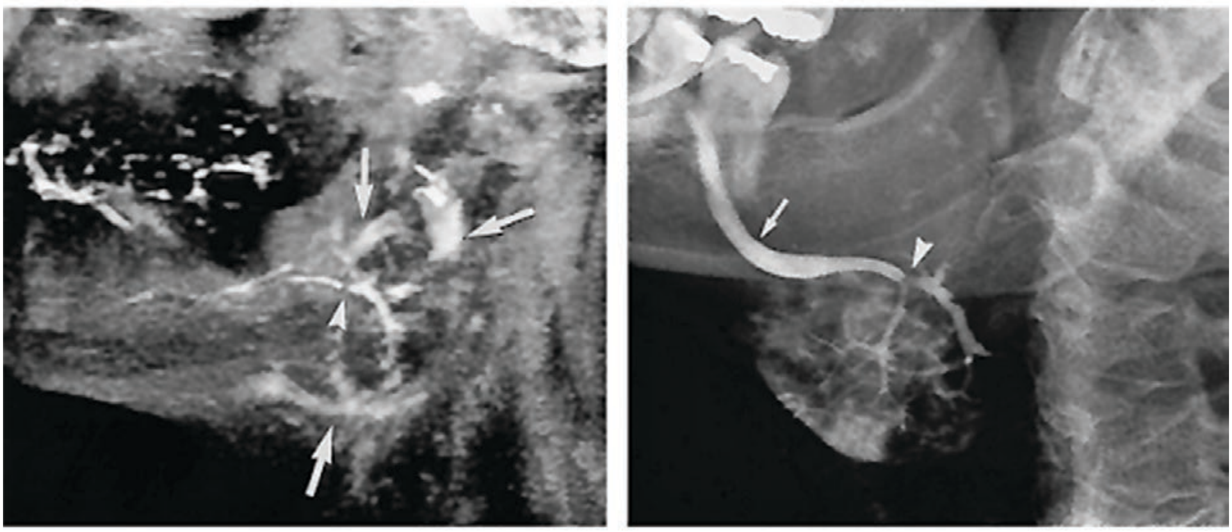

Figure 11. MIP reconstruction on MRI *versus* conventional sialography
Source: https://www.orl-cmf.ch/pdf/2000-sialolithiasis-and-salivary-ductal-stenosis.pdf

Radiološka dijagnostika sijalolitijaze

Sažetak

Postojanje mogućih patoloških stanja žlijezda slinovnica zahtijeva korištenje određenih slikovnih tehnika koje pridonose boljem dijagnosticiranju poremećaja i pravilnom liječenju. Kamenci, upalni procesi i tumori su stanja koja su praćena neugodnim simptomima unutar usne šupljine. Sijalolitijaza je prisutnost kamenaca u žlijezdama slinovnicama i čest je patološki poremećaj. Cilj ovog rada je prikazati radiološku dijagnostiku sijalolitijaze. To uključuje metode dentalne radiografije i različite metode sijalografije. Konvencionalne tehnike snimanja u dentalnoj radiografiji s vremenom su napuštene. Danas se u kliničkoj praksi sve češće koriste metode ultrazvuka i sijalografije. Sijalografske metode uključuju primjenu kontrastnog sredstva, što rezultira boljom vizualizacijom izvodnih kanala žlijezda slinovnica, kako u klasičnom tako i u digitalnom snimanju. Metode CT i MRI sijalografije bolje vizualiziraju manje kamence u izvodnim kanalima slinovnica, uz određena ograničenja. Rezultati pregledanih znanstvenih istraživanja pokazuju da su radiografske metode snimanja sijalolitijaze komplementarne. Sijalografija i ultrazvuk su početne metode u dijagnosticiranju sijalolitijaze, ali uporaba CT-a i MR-a može pružiti vrijedne dodatne dijagnostičke informacije.

Ključne riječi: dentalna radiografija; sijalografija; kamen; sijalolitijaza; žlijezde; žlijezde slinovnice; Whartonov kanal

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