FOLIA MEDICA CRACOVIENSIA
Vol. LXV, 1, 2025: 19–28
PL ISSN 0015-5616 eISSN 2957-0557
DOI: 10.24425/fmc.2024.153282

Are occlusal X-rays still used in X-ray diagnostics? — review

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Abstract: Occlusal X-rays, as intraoral radiographs, have been used in radiological diagnostics in dentistry for ages. Occlusal X-rays cover a larger imaging field and have a complementary function to other intraoral two-dimensional radiographs. Since the introduction of Cone Beam Computed Tomography (CBCT), the use of such X-rays has decreased significantly. Nevertheless, due to patients' low exposure to ionizing radiation, occlusal X-rays provide an alternative to three-dimensional techniques (CBCT). This paper presents state-of-the-art occlusal techniques and discusses their contemporary applications which are currently not limited to dental X-ray diagnostics.

Keywords: Occlusal X-ray, intraoral radiography.

Submitted: 16-Feb-2025; **Accepted in the final form:** 30-Mar-2025; **Published:** 30-May-2025.

Occlusal X-rays are obtained using the X-ray technique, and their name derives from placement of the image recorder in the occlusal plane. The patient bites onto the image recorder. The occlusal technique is also called *sandwich radiography* (due to the similarity: teeth — image recorder — teeth) [1]. Two decades back in dental X-ray diagnostics, basic techniques of tooth and jaw imaging included dental and pantomographic radiographs. These images were complemented by occlusal X-rays. They provided for additional diagnostic information in projections perpendicular to those applied in dental and pantomographic radiographs. Occlusal X-rays introduced a third dimension to these two-dimensional imaging techniques. Currently, the role of occlusal X-rays has been taken over by cone Cone Beam CT. 3D CBCT imaging allows for all sorts of reconstructions of the facial region of the skull. This technique is broadly available and used in all dentistry departments [2].

The concepts of bite and occlusion in the image name (*Occlusal X-ray*) are crucial in the gnathophysiology of the stomatognathic system [3], and are used in prosthetics and orthodontics. Malocclusions (determined according to Angle's classification) refer to the alignment of teeth in the upper and lower arch, in particular to their correct and symmetrical contact over the entire surface. Malocclusion can cause many dental problems. One of the definitions of occlusion in patients with teeth refers to the static contact of occlusal surfaces [4]. The occlusal surfaces and incisal edges of the dental crowns, however, do not form a flat surface and are aligned according to sagital curvature — the Curve of Spee [5]. In turn, in the functional meaning, the occlusal plane extends from the incisal edge of the lower incisor and the distal cusp of the lower molar. Its average angle totals 10–12 degrees vs. the Frankfort horizontal (determined by the *Porion* and *Orbitale* reference points). In the case of edentulous patients with disappearing alveolar processes and alveolar parts of the mandible the occlusal plane differs from that in patients having teeth. Occlusion may also involve "Camper's plane" used in skull measurements and dentistry [6]. According to this author, the plane passes through mandible surfaces of posterior teeth and is parallel to the plane connecting the upper margin of the external acoustic meatus with the lower margin of the pear-shaped aperture, which coincides with the line connecting the lower edge of the nasal wing with the lower edge of the tragus on the face. According to Majewski, this line connects the following points: Porion (the highest point of the external acoustic meatus) and anterior nasal spine [3].

The procedure for taking occlusal X-rays has been standardized in Poland in the list of standard radiological procedures, section: Radiology — imaging diagnostics and surgical radiology under the name: "Radiography, occlusal — maxilla or mandible assessment" (main code: 1.002; ICD 9: 87.120.102) [7]. The procedure is aimed at examining the teeth, the alveolar process of the maxilla and the alveolar part of the mandible, as well as the hard palate or the mandible and the floor of the mouth.

The occlusal technique is an intraoral technique [8], along with the *Paralleling Technique* [9], the *Bisected Angle Technique*, and the *Bite-Wing Technique* [10].

Due to the large imaging field, the vast majority of occlusal X-rays require the use of larger imaging devices than those used for dental images or tooth crowns (standardized format #1: 20 × 30 mm and #2: 31 × 42 mm). The devices used for occlusal X-rays are screenless X-ray films and image plates with dimensions 57 × 76 mm (i.e., standardized format #4). Wired digital devices are not suitable for the occlusal technique because they are too small [11]. In turn, active surface of image plates is prone to mechanical damage. The large diagonal of the occlusal X-ray device (95 mm) and its surface (43 cm^2) determines the visibility of the maxillary and mandible area.

Particular attention must be drawn to artifacts related to occlusal X-rays, referred to as "cone truncation errors", which are caused by misalignment of the radiation beam size to the region of interest. For this reason, application of rectangular collimation for the occlusal technique is impossible [12].

Table 1 presents a comparison of the nomenclature of projections of occlusal X-rays according to different authors. The image recorder is always positioned in the occlusal plane, but the projections differ in the central ray angle vs. its surface. In standard (cross-sectional, or vertex) projections, the central ray follows the median sagittal plane, and the image recorder is placed symmetrically to the plane. In oblique projections, the image recorder is shifted and placed asymmetrically, at an angle vs. the central ray.

The classification of occlusal techniques (Fig. 1) [14] is based on the region of interest and the path of the central ray through the patient's body. Authors: Różyło-Kalinowska [2] and Pasler [11] distinguish occlusal radiographs of the maxilla and the mandible in: standard, vertex, and oblique projections. Vertex projection means that the central ray follows the long axis of the teeth, which have different angle depending on their position in the maxilla and the mandible.

Table 1. Names of radiological projections of occlusal X-rays according to various authors.

region	maxilla			mandible		
radiological projection	isometric projection	vertex projection	oblique projection	isometric projection	vertex projection	oblique projection
name of the radiological procedure	Occlusal X-ray of the maxilla in isometric projection	Occlusal X-ray of the maxilla in axial projection	Occlusal X-ray of the maxilla in oblique projection	Occlusal X-ray of the mandible in isometric projection	Occlusal X-ray of the mandible in axial projection	Occlusal X-ray of the mandible in oblique projection
projection name acc. to Karjodkar [1]	Maxillary Cros-sectional View	The Vertex Occlusal	Maxillary Topographic View — Lateral	Mandibular Cros-sectional View	Mandibular Topographic View — Anterior	Mandibular Topographic View — Lateral
projection name according to Różyło-Kalinowska I. [2]	Standard X-ray of the maxilla	Axial x-ray of the maxilla	Oblique X-ray of the maxilla	Standard X-ray of the mandible	Axial X-ray of the mandible	Oblique X-ray of the mandible
name of the projection according to Pasler A. [11]	Overview occlusal radiographs of the maxilla	None	Half-arch occlusal radiographs of the maxilla	Overview occlusal radiographs of the mandible	Overview radiograph with the patient's head tipped steeply backward and with perpendicular median-sagittal central ray projection onto the image receptor at the level of the first mandibular molars	Half-arch occlusal radiographs of the mandible
name of the projection acc. to Whaites E. [13]	Standard occlusal	Vertex occlusal	Upper Oblique occlusal (oblique occlusal)	Lower 45° occlusal (standard occlusal)	Lower 90° occlusal (true occlusal)	Lower oblique occlusal (oblique occlusal)
name of the projection acc. to White [9]	Anterior maxillary occlusal projection and Lateral maxillary occlusal projection	None	Cross sectional maxillary anterior occlusal projection	Anterior mandibular occlusal projection and Lateral mandibular occlusal projection	Cross sectional mandibular anterior occlusal projection and Lateral mandibular projection	None

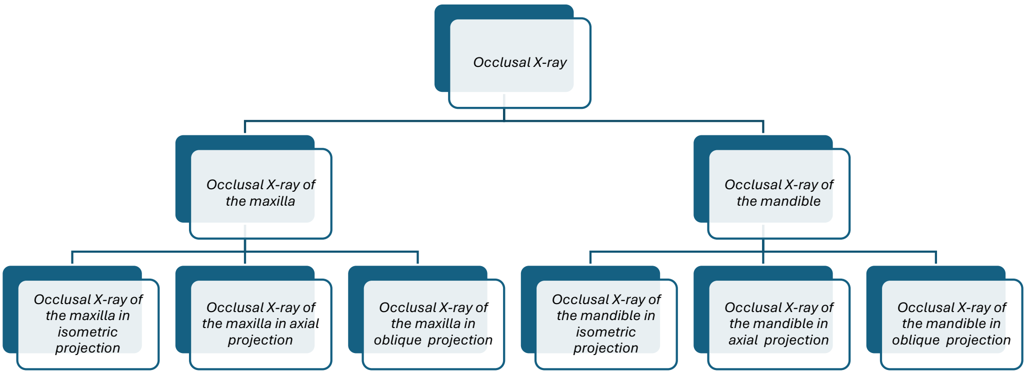


Fig. 1. Presentation of projections of occlusal radiographs according to Różyło T.K. and Różyło-Kalinowska I. [14].

In turn, Karjodkar [1] uses the following nomenclature: Cross-Sectional and Topographic, and additionally classifies paediatric radiographs, not included by other authors. The author also distinguishes two semi-vertex projections to illustrate the anterior region of the maxilla and the mandible: *Maxillary Topographic View — Anterior (45° PC angle vs. recorder plane) and Mandibular Topographic View — Anterior (55° PC angle to the recorder plane)*, as well as *Occlusal View for Tuberosity and Posterior Portion of Maxillary Sinus* and *Occlusal View for Unerupted Third Molar and Submandibular Gland*. Furthermore, for vertex radiograph, the author proposes the use of a cassette with reinforcement screens.

Contrary to other authors presented above, Pasler [11] provides descriptive names for projections of occlusal radiographs. These names describe the angle and route of the central ray, as well as the region of interest (ROI).

Authors included in the list: Whaites [13], Karjodkar [1], Różyło [2] and Pasler [11], additionally distinguish paediatric occlusal radiographs. This is for two fundamental reasons: higher exposure of children to ionizing radiation, and difficulties with locating large image recorders in the occlusal plane in children.

Table 2 presents individual projections of occlusal X-rays described by Karjodkar [1]. The following criteria have been considered here: the name of the projection, the entry point, and central ray path, the position of the patient's head, the setting of the image recorder in the oral cavity, the angle of the beam to the patient's occlusal plane, and the imaging field.

The following anatomical details are visible in the isometric projection of the occlusal X-ray of the maxilla in a patient with permanent dentition: 1. alveolar process in the right and left portion of the maxilla, 2. palatine process of the right and left portion of the maxilla, 3. anterior nasal spine, 4. palatine raphe, 5. incisive foramen and canal, 6. permanent upper teeth, 7. greater palatine foramen and lesser palatine foramina [2].

In turn, the occlusal X-ray of the maxilla in the isometric projection in a patient with permanent dentition shows the following anatomical details: 1. the mandibular body with its alveolar portion, 2. mental protuberance, 3. mental spines, 4. lower teeth, 5. the floor of the mouth and 6. the tongue [2].

Other justifications for the use of occlusal x-rays, both intra- and extraoral, can be found in the literature.

Both pantomographic and occlusal radiographs can visualise submandibular gland calculus satisfactorily still before the patient undergoes a CBCT scan. Kim [15] evidenced the advantage of occlusal radiographs of the floor of the mouth taken at an angle of 70 degrees to the occlusal plane vs. pantomographic images — where higher accuracy of sialositis imaging was adopted as the criterion.

Occlusal X-rays in children are performed as complementary imaging: fractures of teeth, unerupted teeth and dental irregularities, as demonstrated by Ozmen *et al.* from Turkey analysing 356 occlusal X-rays in children aged 1–13 [16]. These radiographs, including dental images, thus fall within the scope of the dental trauma kit.

Other modifications of occlusal techniques involve the use of a smaller image recorder format for 32 × 41 mm dental radiographs and positioning with Kocher forceps on the masticatory surface of the third molar in the mandible or the maxilla [17]. The enhanced gag reflex during placement of the image recorder makes it difficult or even impossible to perform dental x-rays of third molars both in the mandible and maxilla. The application of occlusal projections does not cause such effects in the patient. Furthermore, it makes it possible to take the image of these teeth in the vertex or isometric projection.

Approximately 45–67% of supernumerary teeth are mesiodents located between the medial incisors in the maxilla [18]. When locating the mesiodents, a modification of the axial occlusal technique is applied, called *Vertex occlusal projection*. The central ray of the beam passes along the long axis of the upper medial incisors, from back to front, and from the skull to the patient's legs. The occlusal plane and image recorder are placed horizontally according to vertex occlusal projection technique. The angle between the central ray and the occlusal plane is about 110 degrees and is inclined from the vertical by just 20 degrees.

Interesting applications of extraoral occlusal radiograph recorders include forensics. In forensic science, determining the age and gender of the deceased is of crucial importance. Mizuno [19] proposed to take posterior-frontal radiographs of the skull on occlusal recorders limited to the region of the forehead sinuses taken before and after death to allow identification of people [20] due to the unique and individual architecture of the forehead sinuses.

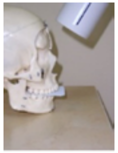
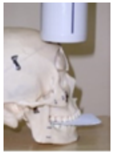
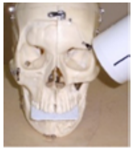
In turn, in veterinary diagnostics, occlusal X-rays of the mandible and the maxilla are used for diagnostics in dental treatment for dogs and cats. Occlusal radiographs are treated as a quick screening test, regardless of the operator's training. In his work, Wada [21] proposed appropriate angles for positioning the central ray of the radiation beam and presented exemplary X-ray images as a guide, which provides educational value and improves the effectiveness of occlusal radiographs in animals.

Occlusal X-rays are made using analogue video recorders without support from amplification screens. In their work, Asieh and other Persian researchers [22] proposed the use of X-ray films and image plates with reinforcement screens. They compared 25 occlusal radiographs made with image recorders: screenless and with matching reinforcement screens. The justifications for the use of amplification screens include: lowering the radiation dose by shortening the exposure time and improving the image quality due to improved contrast and optical density.

In orthodontics, occlusal X-rays are used for morphometric measurements. They serve to assess the symmetry of the arches during the growth period. The trial [23] involved 14 children of both genders with mixed dentition, with either unilateral or bilateral posterior cross bite. Occlusal X-rays were taken at the beginning and end of maxillary expansion. The following variables were measured: intermolar width, interincisal width, interalveolar incisal width, interbasal distance, interarm distance, and angle of incisor inclination. The interapical and interbasal distances were corrected radiographically.

Table 2. Detailed list of occlusal radiographic projections according to Karjodkar [1].

region	maxilla			mandible		
projection	isometric projection	vertex projection	oblique projection	isometric projection	vertex projection	oblique projection
projection name acc. to Karjodkar [1]	*Maxillary Cros-sectional View*	*The Vertex Occlusal*	*Maxillary Topographic View — Lateral*	*Mandibular Cros-sectional View*	*Mandibular Topographic View — Anterior*	*Mandibular Topographic View — Lateral*
central ray path	follows the median plane in the projection of the first molars	according to the median plane — from upper posterior to lower anterior	at an angle of approx. +60 degrees to the patient's occlusal plane — from upper lateral to lower medial	according to the median plane	follows the median plane in the tangential projection between the molars and premolars	obliquely from upper lateral to lower medial
central ray entry point	nasal bridge	tip of the nose	infraorbital orifice region — 2 cm below the crease	floor of the mouth — 3 cm below the mental foramen — in the median plane	floor of the mouth — centre of the mental foramen — in the median plane	body of the mandible in the axis of teeth — in the projection of the first molar
positioning of the head and occlusal plane	patient's occlusion horizontal	head tilted forward	patient's occlusion horizontal	head tilted backward	head tilted backward as far as possible	head tilted backward and turned opposite to the examined side
image recorder placement in the mouth	symmetrically across the mouth	symmetrically across the mouth	asymmetrically along the mouth — outer edge parallel to the lateral arch of the maxilla	symmetrically across the mouth — outer edge parallel to the lateral arch of the maxilla	symmetrically along the mouth — outer edge parallel to the lateral arch of the maxilla	asymmetrically along the mouth — outer edge parallel to the lateral arch of the mandible
central ray [PC] angle to the image recorder plane	+65 – +70°	+110°	+60°	–55°	90°	90°

region	maxilla			mandible		
image field	the hard palate, nasal cavity, teeth from the right second molar to the left second molar, the zygomatic process, nasolacrimal canals, the nasal septum	teeth and alveolar processes in vertex projection	the alveolar ridge of the maxilla or mandible and the teeth of one quarter	the outline of soft tissues of the floor of the mouth, the shadow of the tongue and images of the teeth to the depth of the second molars in the mandible	the anterior portion of the mandible, teeth in the mandible from right canine right to left canine, alveolar portion of the mandible	soft tissues of the floor of the mouth on the examined side, the lingual and buccal plates of the mandible body and the teeth from the canines to the third molars on one side
Photographs of the skull model and positioning of the X-ray tube [own source]	 Photo 1. Isometric projection for occlusal X-ray — side view  Photo 2. Isometric projection for occlusal X-ray — top view	 Photo 3. Vertex projection for occlusal X-ray — side view  Photo 4. Vertex projection for occlusal X-ray — top view 1	 Photo 5. Oblique projection for occlusal X-ray — side view  Photo 6. Oblique projection for occlusal X-ray — top view 1	 Photo 7. Isometric projection for occlusal X-ray — side view	 Photo 8. Vertex projection for occlusal X-ray of the mandible — side view	 Photo 9. Oblique projection for occlusal X-ray of the mandible — side and top view

Photographs of the skull model and positioning of the X-ray tube [own source]:
Photo 1. Isometric projection for occlusal X-ray.
Photo 2. Isometric projection for occlusal X-ray.
Photo 3. Vertex projection for occlusal X-ray.
Photo 4. Vertex projection for occlusal X-ray.
Photo 5. Oblique projection for occlusal X-ray.
Photo 6. Oblique projection for occlusal X-ray.
Photo 7. Isometric projection for occlusal X-ray.
Photo 8. Vertex projection for occlusal X-ray of the mandible.
Photo 9. Oblique projection for occlusal X-ray of the mandible.

Among other uses of occlusal radiographs aside mandibular morphometry, structures of the anterior mandibular and maxillary regions were compared in occlusal X-rays. Taylor [24] compared images obtained with pantomographic and occlusal radiographs taken due to orthodontic indications. Out of the 500 OPG radiographs evaluated, 208 (42%) did not allow for diagnosis in the anterior region. In 33% cases, it was found justified to refer patients to complementary occlusal X-rays that showed the premaxillary space. These were the following cases: 1. unsatisfactory quality of the central part of the image in OPG radiographs, caused by improper positioning of incisors, 2. location of the tooth position using vertical parallax and 3. in case of reasonable suspicion that the pathology had clinical grounds.

Vertex occlusal X-rays with a glued aluminium wedge were used to qualitatively assess bone regeneration. A 2011 study by Marukawe [25] investigated the efficacy of platelet-rich plasma (PRP) in the regeneration of autogenous spongiosa and bone marrow grafted into the alveolar fissure of the maxilla in 20 patients with cleft. In the postsurgical assessment of bone regeneration, occlusal x-rays were used with aluminium wedge to assess the equivalent bone density value. Quantitative assessment of regenerated bone was performed using CT and pantomography at follow-up visits one month, six months, and one year from surgery.

Occlusal X-rays can be used to plan implant grafting procedures. Karjodkar [1] gives examples of the use of metal markers arranged in an acrylic splint in the occlusal plane. X-ray shading markers (metal beads usually 5 mm in diameter) are positioned at the target dental implants sites. The author states that isometric projections (usually at 45 degrees) of the mandible and the maxilla are not suitable for this purpose because they distort the imaged patient's structures. Orthogonal projections can be applied here, showing the anterior segment of the mandible with the mandibular symphysis — symmetrical vertex projection.

Known uses include occlusal radiographs in endodontics described by Lama in 2012 [26]. The study assessed the possibility of using digital image recorders in endodontics. Recorders made in the following technologies were compared: *Charge-Coupled Device* (CCD), *Complementary Metal-Oxide-Semiconductor* (CMOS) and *Phosphor Plate* (PSP). It was evidenced that #4 (57 × 76 mm) imaging plate can be used in the anterior portion of the maxilla and the mandible. The added value of occlusal radiographs of this region is to show the lingual-buccal dimension.

Doses of patient exposure to ionizing radiation during occlusal radiography were estimated as early as in 1995 by Roth [27]. Dose measurements were performed using TLD detectors located on the head and neck of the phantom and divided into groups according to occlusal radiography techniques: isometric and vertex projections for the maxilla and the mandible. The study estimated average radiation doses of 0.0014 cGy to 1.301 cGy (for vertex occlusal x-rays of the arches), which levels them the same as other intraoral radiographs. For isometric occlusal radiographs of the anterior region of the arches, the radiation dose was estimated by Wall [28] as 0.4 cGy. These doses are small compared to CBCT and thus the imaging techniques cannot be performed interchangeably.

Traces of artifacts can be found on occlusal X-ray films caused, for example, by biting. It must be mentioned that traces of this type found on the victim's skin are used in forensics to identify the perpetrator [4]. Artifacts associated with mechanical damage to the substrate and X-ray film emulsion are visible as deformities of the film surface and lighter areas projecting onto the tooth crown image.

Among the indications for occlusal radiographs, there are several frequently repeated indications: 1. location of the canines in the maxilla, 2. detection of remaining unerupted teeth in the maxilla and the mandible, as well as determination of their position in the palatine-linguistic plane, 3. detection and location of salivary stones at the floor of the mouth, 4. assessment of fractures in the anterior region of the maxilla and mandibular body [14].

Conclusion

Among the X-ray techniques used in the diagnostics of the facial part of the skull for dental applications, occlusal radiographs have a complementary function to other two-dimensional intraoral imaging techniques. Due to patients' low exposure to ionizing radiation, according to the ALARA principle, occlusal X-rays provide an alternative to three-dimensional techniques (CBCT). Furthermore, occlusal radiographs provide rapid information about the location and structure of bones, which enriches digital radiodiagnostics. Mandibular occlusal radiographs in the symmetrical vertex projection can be used for comparative measurements of structures distant from the median plane. Additional placement of metal markers in these projections allows planning the location of graft placement in implantology. In turn, the use of an aluminium wedge on the occlusal X-ray proves helpful in radiological assessment of bone density needed in bone regeneration diagnostics.

Funding

This publication was prepared without any external source of funding.

Conflict of interest

None declared.

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