REVIEW ARTICLE

To Implant or not to Implant?: The Role of Imaging

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ABSTRACT

Missing teeth are best replaced by implants, provided the implant is placed in a way that it fulfills esthetic, functional and biomechanical requirements. The assessment of the proposed implant site requires a very specific and accurate data. This could be accomplished by various imaging modalities starting from two-dimensional traditional radiographs to three-dimensional computed tomography and cone beam computed tomography. The purpose of this article is to provide an overview of different imaging modalities, the type of imaging best suited at different time frames of implant placement and effective radiation dose to the patient in these imaging modalities.

Keywords: Implant radiographs, CBCT, CT, OPG.

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INTRODUCTION

Imaging of the dental and periodontal tissues is a critical segment of the comprehensive oral examination, especially for the implant patients where imaging is an important diagnostic adjunct to the clinical assessment.[1]

Dental implants are gaining immense popularity and wide acceptance; because they serve as permanent restorations which replace the missing teeth, improve esthetics and functions like mastication and speech. No tool in dentistry plays a more vital role in treatment planning for implant placement than imaging.[2]

Selection of the ideal implant site is as important as selection of the implant itself, for the desired outcome to be achieved. Undoubtedly, imaging plays a crucial role not only in implant placement but also in postoperative follow-up.[3]

The intent of this article is to provide an overview of different imaging techniques, its advantages, limitations and the type of imaging modality to be employed during different stages of implant placement.

IMAGING OF THE IMPLANT SITE

Vital information should be gathered prior to placement of implant, which will help the clinician in accurate placement and enhance the success of the treatment. Basically the radiographs should be able to reveal any pathosis in the region of implant placement, proximity to vital structures and depict the quantity and quality of bone.

Traditional radiographs can fulfill many of these requirements, but fail to provide the three-dimensional anatomy. This is where the technologies like computed tomography (CT) and cone beam computed tomography (CBCT) gain significant importance along with software's that come in handy for assessment of various parameters.

For the ease of discussion, implant imaging can be divided into the following phases:

1. Preprosthetic implant imaging
2. Surgical and interventional implant imaging
3. Postprosthetic implant imaging
4. Imaging in implant complications.

Preprosthetic Implant Imaging

The objective of this phase of imaging is to identify any pathosis, the relationship of critical structures to the prospective implant sites, the quality, quantity and the angulations of bone at the proposed implant sites.[4]

Intraoral periapical radiograph (IOPAR) of the intended site is always the best way to begin with, as it offers the best resolution and when supplemented with panoramic radiographs it offers immense wealth of information. CT and CBCT accurately capture, display and provide visualization of three-dimensions of maxillofacial anatomy.[5]

Surgical and Interventional Implant Imaging

At times it might be essential to image during the procedure of implant placement, either to know the proximity to the vital structures or the angulation of the implant. Direct digital imaging will be the modality of choice in such a situation, as the images can be acquired instantly and can be visualized on a screen placed just in front of the operator.[6]

Postprosthetic Implant Imaging

This phase begins immediately following the implant placement. Osseointegration of the implant with the surrounding bone is assessed at 0 to 3 months and remodeling is evaluated at 4 to 12 months by periapical and panoramic radiographs. Maintenance of the implant is also essential; thus radiographic evaluation is performed every 3 years. The required information can be obtained by periapical and panoramic radiographs.[5] Different imaging modality at different stages of implant placement is summarized in Table 1.[4-6]

Table 1: Radiographs recommended during various phases of implant placement	
Imaging phases	• Radiographs
Preprosthetic imaging	• IOPAR, OPG • CT, CBCT
Surgical and intervention implant imaging	• Digital • IOPAR
Postprosthetic implant imaging	• IOPAR, OPG, CT,CBCT

IMAGING IN IMPLANT COMPLICATIONS

Complications or failures occur due to improper planning and assessment of the site. This could be due to the poor quality/quantity of bone, poor surgical technique, infection or a systemic condition which will worsen the situation.

Imaging helps in assessing these complications or failures. The most common among them is peri-implantitis, which presents as a thin radiolucent line surrounding the implant. The imaging modality employed during this phase depends on the type of failures or complications.[5]

During this phase, periapical and panoramic radiographs provides good deal of information.

DIFFERENT IMAGING MODALITIES

Periapical Radiographs

Intraoral periapical radiograph (IOPAR) is simple and cost-effective.[1] IOPAR is one of the first radiographs to be made for selecting an implant site. It provides valuable information and greater image detail (Fig. 1).

It is ideal to make these radiographs by employing paralleling technique, as the images obtained are almost similar to the actual size of the object.[5] The images obtained by paralleling technique are geometrically accurate and the technique is easier to standardize, so comparison between different radiographs taken at different intervals is possible.[7,8]

Fig. 1: IOPAR depicting implant in the region of 21

Occlusal Radiographs

Occlusal radiographs reveal larger areas of the maxilla and mandible in comparison to periapical radiograph. The film is held in place by (occlusal/incisal surfaces of the teeth) asking the patient to gently bite on the film packet. It can be employed in patients who cannot tolerate periapical film. It provides cross sectional information of the arch in buccolingual dimension[4] (Fig. 2).

Panoramic Radiography

This radiographic technique is widely employed to assess vertical height of bone, anatomical land marks and to choose a proper implant site. However, due to unequal magnification, coupled with projection errors and lack of cross sectional details this technique has lost its importance; but is still of great value in assessing preliminary implant site and postoperative evaluation along with IOPAR[4] (Fig. 3).

Zonography

Panoramic radiography has been recently modified to obtain the cross sectional detail of the jaw on the resultant image, which is termed as zonography. It provides a good deal of information about the crictical structures in the region of implant placement. The thickness of image layer measures around 5 mm. Due to increased thickness of the image

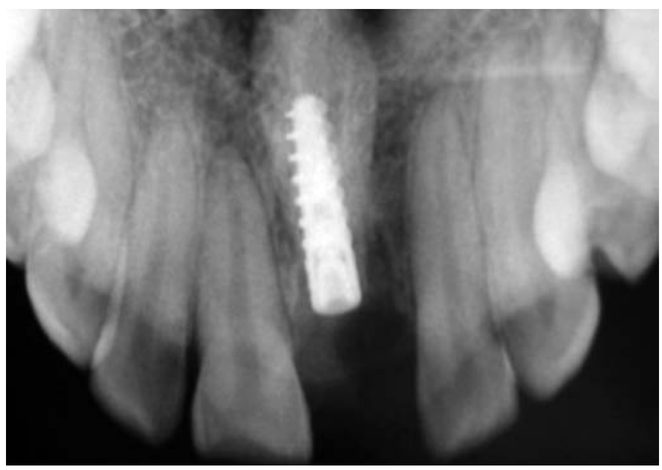


Fig. 2: Occlusal radiograph depicting implant in the region of 21

Fig. 3: OPG depicting implant in the region of 21

layer, application of this imaging modality is restricted to individual sites only.[7]

Digital Radiography

Digital radiography (DR) uses a special sensor (either made up of charged coupled device or complementary metal oxide semiconductors) instead of film to acquire data, which is then displayed on the computer screen. DR can be employed both in intraoral as well as extraoral imaging. In intraoral DR the cord connecting the sensor to docking station sometimes becomes a hindrance while placing the implant. Cordless sensors are available in the market, which are convenient to image while placing the implant.

If intraoral digital images are acquired at the time of surgery, they may be compared with subsequent digital images either by subjective visualization or digital subtraction. Digital subtraction of sequential films is a computerized process that reveals areas of bone resorption/deposition which are not apparent visually, but it requires the image geometry to be reproduced between radiographic examinations. Even subtle bone changes are appreciated on digital subtraction radiography.[5]

The digital imaging offers many advantages over conventional radiography. It eliminates the very need of film and film developing solutions. It provides instant images, lower radiation dose and allows image manipulation (like contrast, density, magnification and image inversion) to improve diagnostic capabilities. The images can be electronically transferred to other clinicians without any alteration of the original image quality.[1, 9]

Computed Tomography

Computed tomography was invented by Sir Godfrey Hounsfield in 1972.[10] It is a digital and mathematical imaging technique that creates tomographic sections where the tomographic layer is not contaminated by structures above and below it.[1,2]

Most importantly, CT enables differentiation and quantification of both soft and hard tissues. CT provides uniform magnification with a high contrast image and well-defined image layer which is free of superimpositions. Three-dimensional reconstruction can be done while studying multiple implant sites, which provides accurate information about bone height and width of the alveolar ridge.[4]

The advantages of CT include—elimination of superimpositions, determines quality, and quantity of bone and allows exact measurements of the length and width of the alveolar ridge. Some of the drawbacks include—metallic artefacts, higher dose of radiation and cost.[4, 6]

Currently there are various generations of CT available, among them most recent ones are helical CT, multidetector helical CT, 256 slice detector.[11]

Helical or spiral CT – acquires images faster and of truly volumetric CT data than is possible with conventional scanners. The images acquired are of high accuracy compared to CT, it heralded the development of a number of techniques, namely referred to as Dentascan imaging.[7,12]

Dentascan Imaging

Dentascan imaging provides programmed reformation, organization and display of the imaging study. It indicates the curvature of the mandibular or maxillary arch and the computer is programmed to generate referenced cross-sectional and tangential/panoramic images of the alveolus along with 3-dimensional images of the arch. The cross-sectional and panoramic images are spaced 1 mm apart and enable accurate preprosthetic treatment planning. Usually, a diagnostic template is necessary to take full advantage of the technique.[4]

This technique provides a means of diagnostic information which is accurate and specific.[2,4]

Images may not be of true size and may require compensation for magnification. Determination of bone quality requires use of the imaging computer/workstation. hard copy Dentascan images include a limited range of the diagnostic gray scale of study; and the tilt of the patient's head during the examination is critical because all the cross-sectional images are perpendicular to the axial imaging plane.[2, 4]

Cone Beam Computed Tomography

CBCT was initially developed for angiography, but more recent medical applications have included radiotherapy guidance and mammography. The cone beam geometry was developed as an alternative to conventional CT using either fan-beam or spiral-scan geometries.[6]

In CBCT systems, the X-ray beam forms a cone shape between the source (apex) and the detector (base) in comparision to conventional fan-beam geometry, where the collimator restricts the X-ray beam to approximately 2D geometry (Fig. 4). While in fan shaped X-ray beam CT, data acquisition requires rotation of the gantry to construct an image set composed of multiple axial sections. CBCT systems can acquire a volumetric dataset with a single rotation of the gantry.[5]

A CBCT produces approximately 300 individual images from a full field of view (FOV), consisting of multiple continuous slices from 1 to 5 mm in thickness depending

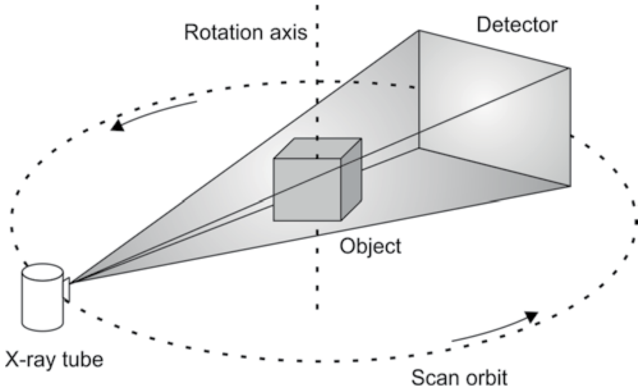


Fig. 4: Representation of cone shaped X-ray beam in CBCT

on the scanner. The FOV is represented as one scan, which can include the entire maxillofacial region including the maxilla, mandible, base of skull and TMJs.[7] CBCT is devoted to maxillofacial area to scan and visualize jaw bone lesions especially cancellous bone. CBCT scanning finds one of its best uses in implant imaging and helps with accurate transfer of preoperative plan to the patient.[6]

Detectors

There are two types of CBCT scanners: charge coupled (IT-CCD) which uses a cesium gas containing X-ray tube and flat panel detector (FP) which uses an area detector. The FP CBCT is similar to conventional helical multidetector CT scanner in which row of detectors have been replaced by area detector of cesium iodide scintillator crystals that converts the X-ray energy into light. The FP provides excellent image with more radiation while the IT-CCD uses lower dose radiation but provides lesser robust images.[13]

In CBCT, voxels are isotropic and range in size from 0.07 to 0.4 mm per side. In CT voxels are anisotropic, decrease in voxel size increases spatial resolution but increases patient radiation dose[14] (Figs 5A and B).

Image Production

The four components of CBCT image production are (1) acquisition configuration, (2) image detection, (3) image reconstruction, and (4) image display.

Modern scanners can fit in the space of a standard panoramic radiograph machine. New machines have scan times of less than 10 seconds. A volume of data is acquired by CBCT, which is then reformatted and three different types of two-dimensional images are synthesized. The three types of two-dimensional CT reconstructions are axial scans, cross-sectional reconstructions and panoramic reconstructions.

Figs 5A and B: Illustration of voxel in (A) CBCT with isotropic voxel and (B) CT with anisotropic voxel

In maxilla, CBCT essentially helps to assess the size of the labial cortical concavity in the lateral incisor region. It also helps to analyze implant relations with anatomical locations like maxillary sinus and incisive foramen.

CBCT scans of the mandible help to determine the size of the lingual concavity in the symphyseal region and posterior region of the mandible. In the inferior alveolar canal (IAC), (Fig. 6). CBCT scans can show whether the canal is single or divided and how it is placed buccolingually[15] (Fig. 7).

Cone Beam Computed Tomography *vs* Computed Tomography

3D images of cone beam CT (CBCT) are becoming more readily available for use in maxillofacial applications. CBCT provides better image quality of teeth and their surrounding structures, compared with conventional CT. It reduces the radiation dose as compared with conventional CT and offers high spatial resolution.[16] The comparison between CT and CBCT is presented in Table 2.[17,18]

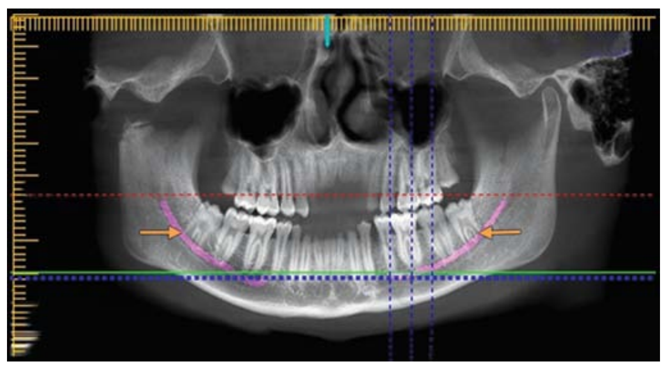


Fig. 6: Tracing of inferior alveolar canal in panaromic section of CBCT

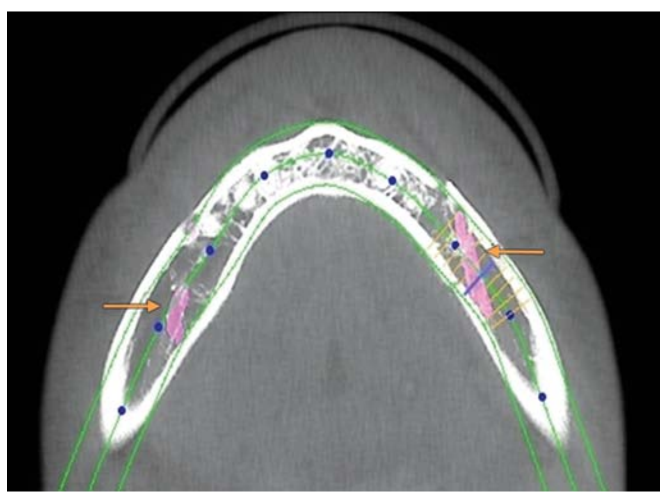


Fig. 7: Axial section showing location of inferior alveolar nerve canal

Table 2: CT *vs* CBCT

Computed tomography	*Cone beam computed tomography*
Fan shaped X-ray beam	Cone shaped X-ray beam
Patient has to lie in supine position	Patient can either sit or stand and head can be stabilized using straps
It uses banana shaped / solid state detector	Flat panel detector
Effective radiation dose is more	Comparatively less
Voxel size is large	Voxel size is small with greater resolution
Scattered radiation is less	More
Metallic artefacts are more	Less
Scan time is more	Less than 30 seconds
Hospital set up is required	It can be used in dental outpatient departments and clinical set ups

Magnetic Resonance Imaging (MRI)

MRI was first introduced by Lauterbur.[19] The major advantage of MRI is no ionizing radiation is used. MRI is based on the phenomenon of nuclear magnetic resonance where in signals from hydrogen nuclei (protons) in water and fat are used to form cross-sectional images of the body. MRI is used in implant imaging as a secondary imaging technique where primary imaging techniques such as tomography or CT fail.[6,19]

MRI has been employed in implant imaging basically to locate IAC, its path and the relationship with proposed implant site.[7] It has the ability to differentiate IAC and neurovascular bundle from adjacent trabecular bone.[20]

Softwares

Several different software packages for CT and CBCT are available in market today like - Denta Scan, SimPlant, and Procera softwares. These programs provide an interactive platform permitting analysis of potential implant sites for bone quantity, quality and morphology.[1]

Simplant software (Columbia Scientific, Inc, Columbia, MD) manufacturer has provided with the capability for the third party to interact with CT scan data on a personal computer, allowing for preoperative simulation of implant placement, prosthetic simulation and bone augmentation simulation that makes Simplant (the state-of-the-art imaging tool for dental implants).[1,6]

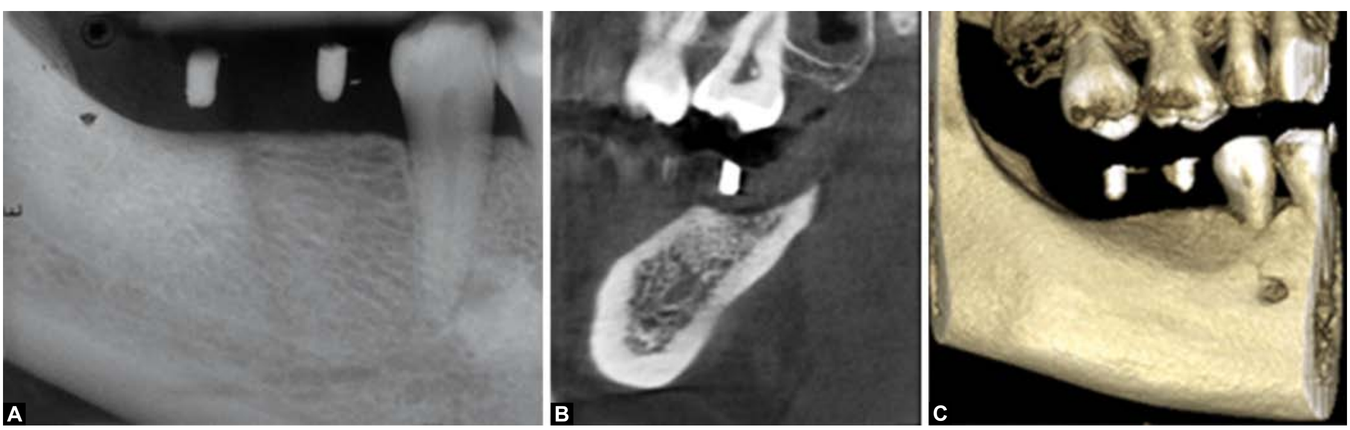
Various tools of the software like 'implant tool' and 'angulations tool' help to choose the appropriate size of the implant and its angulations (buccolingually as well as mesiodistally) according to availability of bone. By clicking on the 'implant icon', the implant can be dragged into position in the region of interest. The implant is immediately exhibited in all the three planes. The clinician can determine the desired implant trajectory and emergence profile.[1]

Imaging Stents

A stent is an appliance used either for radiographic evaluation during treatment planning for assisting in determining the dimension, location and angulation of implant according to available bone, vital structures and proposed prosthesis or during surgical procedures to provide optimum implants placement.[21]

Presurgical imaging can be obtained by the using an imaging stent that helps to correlate radiographic image to a precise anatomic location or potential surgical site. The implant sites can be identified by radiographic spheres or rods retained within an acrylic stent. These can subsequently be used as a surgical guide to orient the insertion angle of the guide bar and ultimately the angle of the implant.

A radiographic guide helps for visualization of the prosthetic tooth, occlusion with opposing tooth, planned implant location, implant angle and thickness of soft tissue between the bone and the tooth[6] (Figs 8A to C). Since, the metallic markers produce artefacts in CT, only nonmetallic radiopaque markers, such as gutta-percha, composite resins are to be used.



Figs 8A to C: Radiographic stent, with radiopaque marker for the proposed implant site as seen in (A) IOPAR, (B) cross sectional CBCT and (C) 3D-imensional CBCT

Table 3: Merits and Demerits of imaging modalities in implant placement along with their radiation doses

Imaging modalities	*Merits*	*Demerits*	*Radiation dose*
IOPAR	Simple technique, cost effective Great image detail and resolution, less radiation.	Less image area two-dimensional Image Elongation and foreshortening.	Single intraoral film -0.0095 μSv Full mouth exposure -34.9-170 μSv
Occlusal radiographs	Determines buccolingual dimension of alveolar ridge. Simple and cost effective	Magnification is more two-dimensional image	0.038 μSv
Panaromic radiographs	Visualization of maxillary and mandibular teeth with surrounding structures and anatomical landmarks. Assessment of vertical height of bone Helps to analyse implant site to anatomical locations Less radiation.	Unequal magnification Lack of details two-dimensional image Geometric distortion	14.2-24.3 μSv
Computed tomography	Eliminates superimpositions Determines quantity and quality of bone Accurate measurement of length and width of alveolar ridge Less distortion and magnification	Cost Radiation is more Training required for interpretation Artefacts are more	CT maxilla-104 μSv CT mandible-761 μSv
Cone beam computed tomography	It helps to analyse implant site and its relation with anatomical structures Determines quantity and quality of bone Uniform magnification Surgical templates and stents can be used to guide placement of implants.	Streak artefacts Training required for interpretation	6 cm FOV maxilla (CBCT-58.9 μSv 6 cm FOV mandible (CBCT)- 96.2 μSv
MRI scan	Nonionizing radiation used It is used to visualize soft tissues and to locate anatomical areas like maxillary sinus, inferior alveolar canal and its relation to implant site It has the ability to differentiate IAC and neurovascular bundle from adjacent trabecular bone	Characterization of bone mineralization is difficult MRI examinations are contraindicated in patients with metal foreign bodies in the eyes, ferromagnetic intracranial aneurysm clips, cardiac pacemakers, cochlear implants.	Nil radiation

Table 4: Depicting values for various implant parameters in different imaging modalities

Parameter	*Conventional 2D imaging*			*3D imaging*		
	IOPAR	*Occlusal radiograph*	*Lateral cephalogram*	*OPG*	*CT*	*CBCT*
Bone height	✓✓	-	✓	✓✓	✓✓✓✓	✓✓✓✓
Bone resorption/Deposition	✓✓✓	-	✓	✓✓	✓✓✓✓	✓✓✓✓
Buccolingual dimension (width)	-	✓✓✓	-	✓✓*	✓✓✓✓	✓✓✓✓
Bone quality	✓✓	✓✓		✓✓	✓✓✓✓	✓✓✓✓
Relation of implant site to anatomical location	✓✓	✓✓	✓	✓✓	✓✓✓✓	✓✓✓✓
Pathology identification	✓✓	✓✓	✓✓	✓✓✓	✓✓✓✓	✓✓✓✓
Determine jaw boundaries	✓✓	-	✓✓✓	✓✓	✓✓✓✓	✓✓✓✓
Long axis of ridge	-	✓✓✓	-	✓✓*	✓✓✓✓	✓✓✓✓

Scoring: Excellent ✓✓✓✓; Good ✓✓✓; Average: ✓✓; Poor: ✓; Nil: Zonography*

Gutta-percha marker has property of thermoplasticity and can be easily removed while conversion of stent from diagnosis to surgical.[22]

Radiation Dose

When a particular imaging modality is chosen for implant imaging, the ALARA principle (as low as reasonably achievable) should be kept in mind. When advising additional radiographs or other imaging modalities only the potential risk *vs* perceived benefits should be weighed.[2] The effective radiation dose along with merits and demerits for different imaging modalities are presented in Table 3.[15,23,24]

CONCLUSION

Traditional imaging modalities have served us for long and will continue do so, but they however will provide us only with a two-dimensional data. With advent of CT and CBCT not only three-dimensional visualization is possible, it also provides the depth and spatial resolution to the implant. With the use of software's and imaging stents not only the placement of implant has become easy but success rates have dramatically improved. The imaging modality which reveals necessary implant parameters is presented in Table 4.[25,26]

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