RESEARCH PAPER

Clinical and CBCT Based Evaluation of Residual Ridge Length in Posterior Partially Edentulous Mandibular Arches for Dental Implant Planning

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ABSTRACT:

Dental implants have proved to be one of the most reliable methods for treating partially edentulous patients. Successful placement of dental implants in posterior regions of the mandible requires careful evaluation of ridge length, width, and height of residual bone relative to the inferior alveolar nerve and mental foramen. Clinical examination alone does not give an exact idea of the residual ridge anatomy due to morphological variations and ridge resorption following tooth extraction. Cone Beam Computed Tomography (CBCT) is an important diagnostic tool providing high-resolution, three-dimensional images of the alveolar bone with minimal distortion and radiation.

This research discusses the significance of residual ridge length analysis for implant therapy in posterior partially edentulous mandibular arches, the anatomy of ridges, methods for evaluating ridge length, importance of CBCT in implantology, patterns of ridge resorption, measurements, clinical application, disadvantages, and prospects of digital planning in implant therapy. The article concludes by comparing clinical examinations with radiographic techniques in ridge length determination and concludes that radiographic examinations prove better than clinical methods.

Importance of digital workflow integration, guided implant surgery, and artificial intelligence-based imaging to enhance implant treatment results is also pointed out in the article. Evaluation of the residual ridge length becomes vital in defining the size of the implant, its inclination angle, number of implants, and necessity of performing bone augmentation.

KEYWORDS: Cone beam computed tomography (CBCT); Residual ridge length; Posterior mandible; Dental implant planning; Partially edentulous arch; Bone loss; Implant dentistry

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INTRODUCTION:

Today, dental implants became one of the most predictable methods for restoring function and aesthetic appearance in edentulous and partially edentulous jaws. It should be mentioned that the main factor determining successful results of implant therapy is bone tissue volume and density at the planned implantation site.[1] In comparison with other jaw regions, the posterior mandible poses the greatest problems due to increased bone resorption rate, presence of dense cortical bone, low bone tissue height, and close anatomic proximity to the inferior alveolar nerve.[2]

After tooth removal, resorption occurs progressively in the alveolar process with regard to ridge width, height, and length. The extent of bone loss is influenced by multiple factors like edentulous time, periodontitis, injury, systemic diseases, and prosthetic loading.[3] Traditional imaging techniques like ridge mapping, panoramic X-rays, and periapical X-rays do not offer precise data due to distortion and inability to measure the three-dimensional structure.[4]

The emergence of Cone Beam Computed Tomography (CBCT) revolutionized implant assessment and diagnosis. CBCT enables the measurement of the alveolar ridge structure, bone density, cortical thickness, and anatomical landmarks with great accuracy. CBCT has been regarded as the gold standard for implants because it provides precise implant placement and minimizes surgical complications in implant dentistry.[5,6]

The residual ridge length in posterior mandible arches is particularly crucial for the determination of:

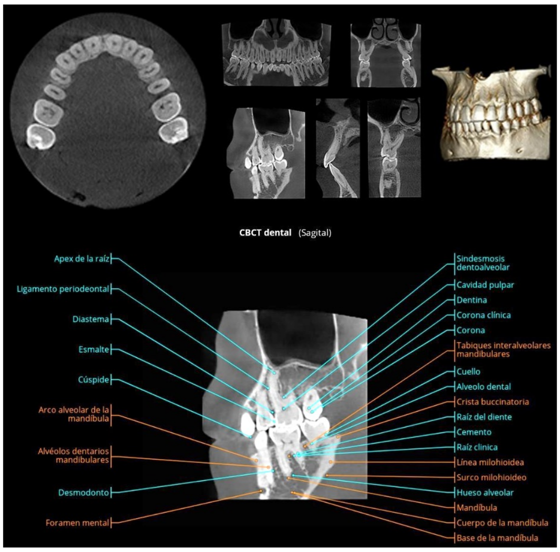
- The size and length of implants
- The distance between implants
- The proximity to the mandibular canal
- Prosthetic space requirement
- Necessity of ridge augmentation
- Guided implant placement[7,8]

ANATOMICAL CONSIDERATIONS OF POSTERIOR MANDIBLE:

Inferior Alveolar Canal

Inferior alveolar canal consists of inferior alveolar nerve and vessels running between mandibular foramen to mental foramen. Injury to this structure during the procedure of placing dental implants can cause paresthesia.[9]

Mental Foramen



The mental foramen usually lies in the area of premolars but there may be variations. CBCT helps locate it accurately before placing implants.

Lingual Undercut

There can be lingual undercuts in posterior mandibular teeth that make it difficult to drill without causing perforation of lingual cortical plate.[10]

Residual Ridge Characteristics

After extraction of teeth, the characteristics of the residual ridge alter due to:

- Vertical Bone Loss
- Horizontal Bone Loss
- Cortical Thinning
- Reduction in ridge length[11,12]

Fig 1: Anatomical Structures Relevant to Posterior Mandibular Implant Planning

RESIDUAL RIDGE RESORPTION

Residual ridge resorption is a chronic, progressive, irreversible process occurring after tooth extraction.

Factors Influencing Ridge Resorption

1. Duration of edentulism
2. Age and gender
3. Systemic diseases
4. Osteoporosis
5. Periodontal disease
6. Occlusal forces
7. Denture wearing habits[13,14]

FLOWCHART REPRESENTATION

Tooth Extraction
↓
Blood Clot Formation
↓
Bone Remodeling
↓
Horizontal Bone Loss
↓
Vertical Bone Loss
↓
Residual Ridge Reduction

CLINICAL EVALUATION OF RESIDUAL RIDGE LENGTH:

The clinical examination continues to be the initial step in implant planning.

METHODS OF CLINICAL EVALUATION:

1. Visual examination

Assessment of

- Alveolar ridge shape
- Keratinization status
- Soft tissue thickness
- Depth of vestibule[15]

2. Palpation

Palpation aids in identifying

- Alveolar ridge sharpness
- Bone undercuts
- Integrity of cortical bone

3. Ridge mapping

Use of calipers and bone sounding under local anesthesia to approximate bone width and shape.[16]

4. Analysis of diagnostic cast

Diagnostic casts aid in analyzing

- Mesiodistal space
- Occlusion relationship
- Prosthetic consideration

LIMITATIONS OF CLINICAL EXAMINATION

- Capability to assess internal bony structure
- Inability to locate mandibular canal
- Estimation error of ridge dimensions
- Bone density cannot be accurately estimated[17,18]

ROLE OF CBCT IN IMPLANT PLANNING:

CBCT offers three-dimensional imaging at higher spatial resolution and reduced radiation dosage as compared to the conventional CT.

Advantages of CBCT

- Accurate measurement
- Three-dimensional imaging

- Less distortion
- Low radiation
- Assessing bone quality
- Identifying landmarks[19,20]

Indication in Posterior Mandible

- Assessing implant sites
- Mandibular canal identification
- Evaluation of ridge width
- Identification of lingual undercuts
- Fabrication of surgical guide

Fig 2: CBCT Evaluation in Posterior Mandibular Implant Planning

CBCT MEASUREMENT PROTOCOL:

Parameters Evaluated

1. Residual ridge length
2. Ridge width
3. Available bone height
4. Distance from mandibular canal
5. Cortical thickness
6. Bone density

Measurement Procedure

1. CBCT scan acquisition
2. Reconstruction of cross-sectional images
3. Identification of anatomical landmarks
4. Linear measurements using software tools
5. Implant simulation[21]

Fig 3: Linear Measurements on CBCT for Implant Planning

TABLE 1: COMPARISON BETWEEN CLINICAL AND CBCT EVALUATION:

Parameter	Clinical Examination	CBCT Evaluation
Ridge Length	Approximate	Highly Accurate
Bone Width	Limited Accuracy	Precise
Bone Height	Difficult	Accurate
Mandibular Canal Localization	Not Possible	Excellent
Lingual Undercut Detection	Difficult	Excellent
Implant Simulation	Not Possible	Possible
Bone Density Assessment	Not Possible	Possible

SIGNIFICANCE OF RESIDUAL RIDGE LENGTH IN IMPLANT PLANNING:

Residual ridge length directly influences:

- Number of implants
- Implant dimensions
- Inter-implant spacing
- Prosthetic design
- Load distribution

Recommended Inter-Implant Distances

- Implant to implant: 3 mm
- Implant to natural tooth: 1.5–2 mm
- Implant to mandibular canal: 2 mm safety zone[22]

CBCT FINDINGS IN POSTERIOR PARTIALLY EDENTULOUS MANDIBLES:

Common findings include:

- Reduced ridge width
- Vertical bone loss
- Buccal cortical thinning
- Lingual concavity
- Proximity of mandibular canal
- Reduced mesiodistal ridge length

TABLE 2: TYPICAL CBCT MEASUREMENTS IN POSTERIOR MANDIBULAR IMPLANT SITES

Site	Mean Ridge Width (mm)	Mean Bone Height (mm)	Mean Ridge Length (mm)
First Premolar	6.5–7.2	14–16	9–11
Second Premolar	6.0–6.8	13–15	8–10
First Molar	5.5–6.5	11–14	10–12
Second Molar	5.0–6.0	10–13	9–11

DIGITAL IMPLANT PLANNING:

Modern implant dentistry integrates CBCT with digital workflows.

Components of Digital Planning

1. CBCT imaging
2. Intraoral scanning
3. Virtual implant placement
4. Surgical guide fabrication
5. Guided implant surgery[23]

Advantages

- Increased precision
- Reduced surgical time
- Minimally invasive surgery
- Improved prosthetic outcomes

Fig 4: Digital Workflow in Implant Dentistry

Fig 5: Workflow illustrating the conventional and digital protocols for fabrication of a radiographic template and computer-guided surgical guide in implant planning.

Fig 6: Sequential digital implant planning and guided implant placement workflow in a posterior mandibular edentulous area using CBCT imaging and a stereolithographic surgical guide.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN CBCT ANALYSIS:

Artificial intelligence (AI) has recently been integrated into CBCT analysis for:

- Automatic mandibular canal detection
- Bone density analysis
- Implant positioning
- Risk assessment
- Surgical guide optimization

AI-assisted diagnostics improve efficiency and reduce operator variability.[24,25]

CHALLENGES AND LIMITATIONS:

Limitations of CBCT:

- Radiation exposure
- Motion artifacts
- Metal artifacts
- High equipment cost
- Need for specialized training

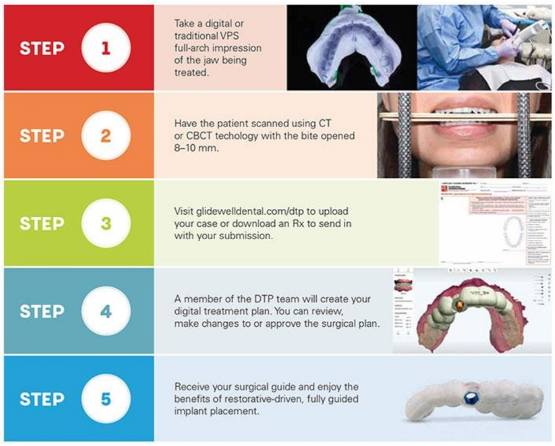
Clinical Limitations:

- Soft tissue evaluation limitations
- Dependence on software calibration
- Variability in image interpretation[26,27]

FUTURE PERSPECTIVES:

Future developments may include:

- AI-assisted implant planning
- Dynamic navigation surgery
- Robotic implant placement
- Real-time intraoperative CBCT
- 3D bioprinted bone scaffolds
- Personalized digital implant workflows[28,29]



FLOWCHART: CBCT-BASED IMPLANT PLANNING

Patient Examination
↓
Clinical Ridge Assessment
↓
CBCT Imaging
↓
3D Reconstruction
↓
Residual Ridge Measurement
↓
Virtual Implant Placement
↓
Surgical Guide Fabrication
↓
Implant Surgery
↓
Prosthetic Rehabilitation

CONCLUSION:

The clinical as well as the use of CBCT for the assessment of the residual ridge length in the posterior partially edentulous mandibular arches is of key importance in the successful planning of the dental implants. Even though the clinical assessment gives a rough idea about the morphology of the residual ridge and the surrounding tissues, CBCT provides detailed imaging of the structure of the alveolar bone and its relation to adjacent structures.

Assessment of the exact measurements of the residual ridge can aid dentists to choose the right size of the implant, angle of placement, and prosthetic design while reducing risks of damaging the inferior alveolar nerve and perforating the cortex bone.

CBCT combined with guided surgery and artificial intelligence presents the future direction of implantology.

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