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Dental Soft Tissues and Palatal Masticatory Mucosa from the Periodontal and Radiographic Perspectives: A Review Article

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Abstract:- This review article delves into the advancements in the assessment and management of palatal masticatory mucosa, with a particular emphasis on the thickness of the palatal mucosa and its implications for periodontal and peri-implant surgeries. It highlights the pivotal role of cone beam computed tomography (CBCT) in evaluating Thickening of the palatal mucosa, despite its inherent limitations in soft tissue visualization. The paper discusses the evolution of mucogingival surgery, including the classification of marginal tissue recession and soft tissue grafts, and examines the histology of palatal mucosa. It also evaluates the indications, predictability, and clinical as well as aesthetic outcomes of free gingival graft (FGG) & connective tissue graft (CTG) procedures. Various methodologies to measure palatal mucosa thickness are explored, alongside strategies to overcome CBCT's limitations in soft tissue assessment. The review underscores the significance of a comprehensive understanding of palatal masticatory mucosa's anatomy and histology, alongside the surgical techniques available for managing mucogingival deficiencies. It aims to enhance the predictability and aesthetics of periodontal and peri-implant surgeries through advancements in diagnostic and surgical techniques, coupled with a deeper understanding of tissue biology.

Keywords:- *Thickening of the Palatal Mucosa, Cone Beam, Soft Tissue Computed Tomography is Achieved.*

I. INTRODUCTION

Soft tissue augmentation procedures are frequently engaged in solve various mucogingival problems, including gingival recessions, insufficient thin gingival biotype, keratinized mucosa & peri-implant soft tissue deficiency. Assessing the thickness of palatal masticatory mucosa is crucial for planning periodontal & peri-implant graft surgeries [1, 2].

Thickening of STG is an important role in graft survival, the healing process, and clinical outcomes following mucogingival surgery [3]. It is a critical determinant in selecting t determining the most suitable treatment strategy and predicted prognosis [4]. The hard palate and tuberosity are the primary donor sites for STG in the oral cavity [5]. The keratinized mucosa adjacent to the maxillary premolars is commonly utilized for harvesting full epithelialized FG grafts or sub-epithelial CT grafts in oral & periodontal soft tissue augmentation procedures [6, 7].

- *Progress of Mucogingival Surgery:*

In 1957, Friedman introduced the term mucogingival surgery to correct the relation between gingiva and mucosa around teeth [8]. Over the subsequent decades, this term has evolved to encompass various procedures aimed at correcting and modifying defects, as well as adjusting the position, width & thickness of keratinized tissue surrounding teeth. With the expansion of implantology, the growing demand for aesthetically pleasing prosthetic replacements, for edentulous ridges and implants supported by pontics and detachable prostheses, periodontal plastic surgery techniques have been developed. Miller introduced the term "periodontal plastic surgery" in 1988 [9], which now includes procedures aimed at preventing or correcting oral soft tissue defects of various origins, including those that are anatomical, developmental, traumatic, or disease related.

It is very important for long-term success & stability in both function & appearance that there is healthy tissue connected to the implant at the point where the tooth meets it. [10]. In addition to facilitating the deposition of plaque around dental implants and teeth, keratinized tissue deficiency may be leading to the recess of the free soft tissue margin, especially in the esthetic zone. A thick periodontal phenotype decreased susceptibility to decline due to the cortical bone thickness and gingiva that surrounded [10]. Mucogingival deficiency management is now an essential component of dental procedures involving both natural teeth & implants. The significance of sufficient KT surrounding teeth has been the subject of extensive research for decades. [11], with consequence sets that extend into the field of implantology. Strongly correlated with optimal soft & rigid tissue health is the existence of gingiva. In patients who keep normal oral hygiene, however, the lack of affixed

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gingiva surrounding teeth does not invariably lead to a higher prevalence of soft tissue recession. When combined with effective plaque control, even minute quantities of kT have been shown to enhance the long-term stability of the soft tissue margin, according to long-term studies. [12].

Marginal tissue recession refers to the process by which soft tissue is displaced apically away from the cementoenamel junction, resulting in the tooth root surface becoming exposed. [13]. While the expression "gingival recession" is frequently employed interchangeably, it has been suggested that the displaced tissue may originate from alveolar mucosa rather than gingiva [13]. Exposing a tooth root can lead to hypersensitivity to temperature extremes, exposure to potentially cariogenic microorganisms, and noticeable esthetic problems [13]. Multiple mechanical, thermal, and chemical insults, as well as the accumulation of plaque and inflammation of the gingiva, result from poor oral hygiene and orthodontic tooth movement are the primary causes of gingival recession [14]. Individuals suffering from thin gingival biotypes and those whose keratinized tissue is diminished or nonexistent are particularly prone to gingival recession [15].

In order to assess the necessity of soft-tissue transplantation prior to implant therapy and during periodontal plastic surgical procedures aimed at correcting defects caused by teeth, the following is determined: precise identification & classification of marginal tissue recession are important. To determine the degree of marginal tissue recession, multiple categories have been developed. In the year 1968, a system was showed that categorized defects into "shallow-narrow," "shallow-wide," "deep-narrow," and "deep-wide" Depending on the length & the width of the recession defect. These classifications were applied in order estimate the efficiency of tissue-grafting techniques. [16].

Following this, in 1985, Miller put forth an expanded classification system in which the extent of the loss of hard tissue and soft tissue between the teeth is taken into consideration, as well as the location of the apicalmost aspect of the marginal tissue defect in relation to the mucogingival junction. Miller thought that the previous classification system posed a significant challenge in identifying many cases of recession. Systematically predicting the prognosis of STG utilized for root coverage is possible according to the Miller classification. In most cases, defects of classes I & II lead to complete root coverage. Class III defects are characterized by partial root coverage; the surgeon can estimate this extent by horizontally positioning a At the level of the midfacial tissue of the two adjacent teeth to the recessioning tooth, insert a periodontal probe. Class IV defects frequently fail to attain root coverage. [17].

The updated classification system for periodontal conditions surrounding teeth & edentulous ridges was the 2017 World Workshop classification system for periodontal, peri-implant diseases & conditions, which was adopted by the American Academy of Periodontology in 2017. [18]. Cairo *et al.* proposed a contemporary recession categorized according to measuring of interdental CAL [19].

- *Recession Type 1 (RT1):*

Refers GRs without any interproximal attachment loss, In conditions where the cementoenamel junction (CEJ) is not observable clinically from both the distal & mesial surfaces of the tooth.

- *Recession Type 2 (RT2):*

GRs accompanied by Lack of interproximal adhesion is indicated. When the interproximal CEJ is extended to the depth of the interproximal sulcus/pocket, the extent of Lack of interproximal adhesion is equal to or lower than when the buccal CEJ is extended to the apical end of the buccal sulcus/pocket.

- *Recession Type 3 (RT3):*

This condition is indicative of GRs & Lack of interproximal adhesion, in which the interproximal attachment loss exceeds the Lack of buccall adhesion (as measured from the buccal CEJ to the apical end of the sulcus/pocket). [20].

The present classification system addresses particular defects identified in the commonly used Miller classification. These limitations include challenges in distinguishing between Class I & II recession types, the reliance on "bone or soft tissue loss" as a reference for diagnosing pDamage to the periodontal in the interdental region. Additionally, the Miller classification was formulated during the early stages of root coverage techniques, and the expected outcomes for root coverage in the four Miller classes no longer align with the findings achieved using advanced surgical procedures [21]. Moreover, the 2017 classification incorporates more details, including the magnitude of gingival attachment, the degree of recession, the presence or absence of caries and non-carious cervical lesions, the patient's concerns regarding their appearance, and the possibility of dentin hypersensitivity are all factors that should be considered. [22].

Although dental implant success rates exceed 95% when assessed in terms of osseointegration, there are common occurrences of esthetic and biological complications associated with implants. Notably, the downward displacement of peri-implant soft tissues, typically denoted as peri-implant soft-tissue dehiscence (PISTD), mucosal dehiscence or mucosal recession, presents a significant concern. Currently, nothing is universally admitted. classification for mucosal dehiscence around implants. Certain researchers propose employing the exposure of the metallic implant or abutment surface as a point of reference, while others propose comparing the contiguous mucosal margin levels surrounding the natural dentition. Research findings suggest that insufficient dimensions of kT, in conjunction with poor oral hygiene practices, can contribute to increased plaque aggregation around implants and elevate the risk of peri-implantitis [23].

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➢ *Soft Tissue Grafting*

A specialized branch of periodontology which called periodontal plastic surgery, primarily eliminate or correct mucogingival deformities related to insufficient attached gingiva, shallow vestibules, and abnormal frenula through multiple mucogingival surgical techniques aim to halt gingival recession progression and improve esthetics. Among these techniques, free gingival autograft is commonly employed to treat gingival recession in areas with inadequate attached gingiva, especially in the mandibular anterior region. For enhancing tissue thickness, restoring adequate keratinized tissue width, eliminating mucogingival problems, and enhancing esthetics at both natural teeth and dental implant sites. Therefore, STG has gained prominence within the context of clinical practice [24].

Multiple principles are crucial for successful oral soft tissue grafting. Adequate nourishment of the graft is paramount, with soft tissue survival initially relying on plasmic imbibition and subsequent neovascularization. The proximity of soft tissue adaptations decreases the distance required for plasmic diffusion and capillary formation. Additionally, it is critical to achieve hemostasis at the site of the graft, as active hemorrhage and blood products prevent graft adaptation and nutrient delivery. potentially leading to graft loss. Periosteum is often favored as a recipient site due to its abundant vasculature, immobility, and ability to facilitate firm graft adaptation [25].

Effective planning and precise graft harvesting from the donor site are vital, ensuring uniform thickness of the harvested graft to facilitate angiogenesis and nutrient diffusion by encouraging stable and intimate adaptation at the recipient site. Aspects of concern concerning secondary contracture highlight the preference for thicker grafts, which better maintain their dimension's post-contracture [25].

Classifying soft tissue grafting materials hinges on whether they contain vital cells or have undergone decellularization. Autogenous grafts typically retain the patient's vital cells, while allogeneic and xenogeneic materials undergo decellularization. Clinicians can follow established decision trees for grafting technique selection, as proposed in 2011, after reviewing these classifications [26].

Allogenic or xenogenic grafting materials which don't have vital cells Provide alternatives for soft tissue augmentation to autologous soft tissue transplants. mainly expanding the width of KT, these substances are predominantly employed to augment its thickness [27]. As alternatives to autogenous CTG, allografts, including acellular dermal matrix (ADM), have been utilized in proximity of implants and teeth. This is especially true for larger recipient sites or situations where getting autogenous tissue is unfeasible or would cause considerably greater postoperative discomfort. An evaluation of the effectiveness of FGG versus ADM in enhancing the width of affixed gingiva showed that tissue developed at ADM-treated locations lacked mucosal characteristics and more closely resembled scar tissue. [28].

Xenografts have emerged as alternatives to allografts or autografts for use in FG or CTG, featuring thick collagen matrices. Research showed that a xenogeneic collagen matrix with CAF presents a viable alternative to SCTG in treating recession defects, without the morbidity associated with STG harvesting [29]. A systematic review comparing esthetic soft tissue management for dental implants & teeth found that while the xenogeneic collagen matrix achieved equivalent root coverage, it failed to obtain mean keratinized tissue gain comparable to SCTG. [30]. In the same way, an additional systematic review assessing the efficiency methodologies for soft tissue management in around of dental implants preferred the strategy that employed a collagen matrix derived from animals. achieved its objectives but resulted in a compromised esthetic outcome [31].

➢ *Autogenous Soft Tissue Graft*

Autogenous soft tissue graft containing vital cells primarily consisting of fibroblasts in the connective tissue layers & keratinocytes in the epithelial layers., offer the potential for creeping attachment & KT exhibiting a greater width when used to correct recession problems [32]. Autogenous STG can be categorized based on their blood supply into two distinct groups. The first group comprises autogenous grafts that retain their blood supply from donor sites so, the preservation of blood supply often leads to improved postoperative healing outcomes. Such cases include apically positioned flap (APF), coronally advanced flap (CAF), rotational flaps, pedicle sliding grafts, double papilla flap, semilunar flap, and palatal advanced flap. The second group consists of autogenous grafts that are deprived of their original blood supply, such as free gingival grafts (FGG), de-epithelialized CTG & SCTG. Establishing adequate contact among the free graft & the recipient tissue bed is crucial for promoting revascularization between the bed & the pre-existing vessels within the graft, thereby ensuring their survival. [27].

The oral mucosa from either the palate or the maxillary tuberosity is the main intraoral donor site for STG & the tissues harvested from the maxillary tuberosity are typically thicker than those from the palate, while palate-harvested tissues offer a larger surface area [33].

➢ *Palatal Mucosa:*

The palatal mucosa is composed of three distinct layers: the lamina propria (LP), a dense connective tissue that supports the oral epithelium; the keratinized stratified squamous epithelium, which provides frictional resistance; and the submucosa layer, which comprises adipose & glandular tissues and envelops the palatal neurovascular bundle beneath the LP. [34]. In the anterior hard palate region where the mucoperiosteum is present, Sharpey's fibers within the submucosa layer tightly anchor the LP to the periosteum, making separation challenging [35].

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The primary route for vascular supply to the hard palate is the Greater Palatine Artery (GPA). This artery originates the descending palatine artery, which ascends towards the nasal cavity via the incisive foramen after passing through the bony groove of the palate via the greater palatine foramen. The palatine spine is an anatomical structure that partitions the palatal fissure into medial & lateral segments. The Greater Palatine Artery passes through the lateral groove in this particular arrangement, whereas the greater palatine nerve traverses the medial groove. groove [34].

II. TYPES OF PALATAL GRAFTS

➢ *The Free Gingival Graft*

FGG is termed as STG obtained from the palate with its covering epithelium, started by introducing solve the developmental absence or loss of KT. Multiple investigation into the healing process and underlying principles influencing FGG results have significantly enhanced the procedure's predictability.. [36].

To restore adequate keratinized tissue width (KTW) & gingival thickness in cases of mucogingival deformities was the first choice is free gingival graft which confirmed by long-term assessments comparing FGG-treated sites with untreated contralateral sites, have demonstrated gingival margin position stability and gingival recession (GR) prevention subsequent to FGG procedures. At untreated contralateral sites, on the other hand, recession depth was frequently increased, and GRs frequently formed. [37]. Partially epithelialized FGG is a modification was inserted in the lower anterior region to address aesthetic defects that had been reported. and improve mean root coverage percentages while facilitating optimal repositioning of the alveolar mucosa [38].

A lack of or minimal keratinized mucosa surrounding implants has been associated with compromised patient oral hygiene, which results in increased soft tissue inflammation, tissue recession & attachment lost. Teeth with inadequate keratinized tissue width are more susceptible to further attachment loss., so the significance of having adequate KTW and thickness of kT is vital for both natural teeth & dental implants [39]. Despite varying opinions on the role of KTW in peri-implant health maintenance, Research efforts have demonstrated the efficiency of of FGG in reducing mucositis, Improving the management of plaque around implants that are deficient in KTW and decreasing patient discomfort. [40].

Maintaining at least two mm of keratinized tissue width discovered to possess a protective effect on peri-implant health, while implants having less than two mm of at KTW being more prone to developing peri-implant soft & hard tissue complications, so a study concluded that autogenous grafts for soft tissue Augmentation is a highly dependable method for improving the health of the area surrounding the implant through raising the width & thickening of KT. [41–43].

Inadequate preparation of the recipient site, insufficient thickness & graft size, suboptimal adjustment to the recipient bed & the absence of graft stabilization has been recognized as determinants of risk to the outcomes of Free Gingival Grafts. Considering the substantial shrinkage experienced by FGG in course of the recovery phase, typically around 30%, it is advisable to harvest a graft wider than the augmentation site [44]. Recent research has compared the shrinkage of free gingival graft to that of flaps positioned apically alone or alternative grafts, including xenogenic graft and allogenic graft. [45].

➢ *The Connective Tissue Graft*

The shift from traditional mucogingival surgery to periodontal plastic surgery is marked by the introduction of CTG & the increasing adoption of (CTG) over (FGG) [46]. Modern periodontal surgeries emphasize achieving optimal esthetic outcomes to overcome traditional approaches focused primarily on increasing keratinized tissue width [47]. Extensive evidence supports the preference for connective tissue graft in treating GRs or mucosal Rs at both implant sites & teeth as it enhances soft tissue thickness, conceals discolored roots or visible implant components & aids in interdental papilla regeneration [48].

CTG is speculated to act as a biologic filler, improving flap adaptation & stability to the root during early wound repair, resulting in thicker gingival phenotypes and a higher potential for complete root coverage [49]. In contrast, while FGG may retain the original appearance of palatal ST at the recipient site, it can result in poor esthetic integration & a texture resembling scar tissue, whereas CTG can enhance the quality& volume of soft tissue, achieve a harmonious gingival margin [44]. Advancements in techniques and the adoption of microsurgical approaches have contributed to enhanced predictability in root coverage procedures over the past decade [50].

For peri-implant soft tissue dehiscence treatment, Regardless of the width or thickness of the keratinized mucosa, CTG is strongly advised. In contrast, autogolous graft substitutes are frequently employed to augment tissue thickness and reduce postoperative mucosal recession that may occur during immediate implant placement or upon uncovering the implant. [51]. Different methodologies have been suggested in order to procure CTG from the palate, including the trap door, parallel & single incision techniques., aiming to achieve 1ry intention healing with reduced postoperative morbidity compared to FGG, which typically heals by 2nd intention [52].

It has been demonstrated that CTG can be harvested & de-epithelializing free gingival graft, with comparable patient distress to conventional trap door techniques, so long as the donor site of the FGG is adequately protected. Additionally, techniques aimed at minimizing patient morbidity & enhancing palatal wound healing after FGG harvesting have been proposed [53].

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The harvesting technique may influence graft quality, A CTG obtained through de-epithelialization of the FGG consists primarily of LP, whereas a CTG obtained through conventional deep palatal harvesting is more abundant in glandular & adipose tissue. The previously mentioned differentiation makes a CTG firmer, stable & easier in comparison to one obtained from deep palate tissue. [54]. Furthermore, the glandular &adipose tissue of the graft may act as barriers to plasmatic diffusion & vascularization during the initial healing phase, potentially hindering epithelial keratinization [53].

In contrast to CTG extracted from the deep lateral palate, the maxillary tuberosity presents a viable substitute donor site for soft tissue grafting. It entails reduced patient morbidity and comprises a greater quantity of LP & a lesser quantity of submucosa. Even so, the extent to which graft composition influences mucogingival surgery outcomes remain unclear [55].

An additional potential limitation factorv for palatal harvesting is palatal masticatory mucosa, with less residual soft tissue thickness correlated with heightened analgesic consumption , heightened risk of over-thinning the primary flap, result in increased patient morbidity & wound sloughing. [54]. Palatal mucosa thickness varies across different regions of the palate, with special attention required to avoid outcomes like hemorrhage & paresthesia by preventing damage to the palatal neurovascular bundle during soft tissue grafting procedures [56]. Histometric analysis has shown a reduction in LP thickness containing dense connective tissue around the posterior palatal area & mid-palatal suture, alongside thickening of the submucosa containing adipose & glandular tissues [57]. In particular, the palatal mucosal thickness surrounding the first molar tooth region is considerably reduced in comparison to neighboring areas. This can be attributed to the formation of a protrusion at the alveolar crest by the palatal root of the first molar tooth. [58].

III. METHODS AVAILABLE FOR EVALUATING PALATAL MUCOSA THICKNESS

Assessing the thickness of the palatal masticatory mucosa before surgery is essential due to significant variability among individuals. Several methods have been proposed for this assessment, including bone sounding, ultrasound, 3D dental, conventional CT, cone beam computed tomography (CBCT) & MRI [59].

➢ *Bone Sounding Technique:*

This requires minimal local anesthesia and direct clinical measurement with a periodontal probe. before penetrating the mucosa, but it is considered an invasive technique [60].

➢ *Ultrasound Technique:*

By employing ultrasonic sound waves, this approach operates on the principle that a handheld transducer emits the ultrasonic beam & receives the reflected echoes. Although it can be advantageous in evaluating masses of soft tissue, its effectiveness is constrained when the target region is in close proximity to osseous formations. It is utilized in the maxillofacial region to evaluate inflammation and calcifications of salivary glands and ducts, muscle thickness, Sjogren syndrome, and thyroid, parathyroid, and lymph node pathology. [60]. A study utilizing color Doppler ultrasound concluded that accurate localization of the greater palatine artery (GPA) and measuring thickening of palatine fibromucosa are feasible, aiding in therapeutic decisions regarding autograft usage and determining optimal graft harvesting areas to prevent bleeding complications [61].

➢ *Magnetic Resonance Imaging Technique (MRI):*

MRI offers excellent visualization of soft tissues without ionizing radiation. Despite previous limitations, recent technical advancements such as parallel imaging methods, high field strength systems, 3D techniques & dedicated coil systems have expanded its potential applications in dental imaging [62]. A 3D dental MRI technique has been developed for high-contrast visualization of hard & soft tissues. Through this non-ionizing &non-invasive approach, a prospective *in vivo* study evaluated whether dental MRI allows assessment of palatal masticatory mucosa thickness at established measurement points, alongside analyzing the effects of age & gender on mucosal thickness [63].

➢ *Computed Tomography (CT):*

Computed tomography offers superior contrast resolution approaching 1 Hounsfield Unit (HU). It is preferred for diagnoses where soft tissue contrast is critical, as it possesses adequate gray-scale sensitivity to distinguish differences among soft tissues, like distinguishing among fluids & solid tumors. However, a notable drawback of CT is its high radiation dose. Despite being available for over four decades, its limited application in dentistry is attributable to the high cost of apparatus. [64].

Soft-tissue window CT enables the differentiation of soft tissue structures with slight density variations and conducts a precise evaluation of tissue density using Hounsfield units as a standard (-1,000 HU for air, 0 HU for water, and ±1,000 HU for cortical bone). [65]. Contrast agents might have administered intravenously during CT scanning to enhance soft tissue & vascular details. CT is particularly useful for diagnosing and assessing the extent of infections, cysts, tumors & trauma, offering valuable insights into their involvement. It is also the preferred modality When comprehensive soft tissue characterization is necessary, this method can be utilized to distinguish soft tissue lesions from osseous lesions via soft tissue extension. [66].

Despite its advantages, limitations such as CT's use in dentistry is constrained by its high radiation dose, high cost, limited availability, poor resolution, lengthy scanning time, and interpretation challenges. CBCT, which presents numerous potential benefits in comparison to conventional CT for oral and maxillofacial imaging, may reduce a portion of these limitations. [67].

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➢ *Cone Beam Computed Tomography (CBCT)*

CBCT technology, originally devised for angiography at the beginning of the 1980s, has undergone significant evolution, finding a wide array of applications [68]. It represents a distinctive evolutionary path in imaging in contrast to convention CT [69]. Widely embraced in both dental and medical realms, CBCT has emerged as a favored imaging tool, assisting clinicians in diverse diagnostic pursuits and elevating the standard of patient care [70,71].

The term "cone beam" denotes the conical configuration of the X-ray beam utilized in CBCT imaging, which orbits around the patient's head axis, diverging from the fan-shaped beam and intricate scanning motion characteristic of multidetector-row computed tomography (MDCT) in medical imaging. CBCT facilitates the three-dimensional evaluation of hard tissues in the maxillofacial region [72]. Its introduction has precipitated a transition from two-dimensional (2D) to volumetric imaging in maxillofacial diagnostics [73].

The operational principle of CBCT mirrors the fundamental CT technique, wherein the X-ray tube irradiates the patient from one side, while an imaging detector measures the attenuated X-rays on the opposing side as both rotate around the patient [74]. During rotational scanning, the exposure may be continuous or pulsed, with the latter becoming more prevalent. favored in dental CBCT for reduced effective exposure time and patient dose [75]. X-ray attenuation adheres to the basic physical The interactions among radiation & the atomic makeup of the patient's anatomy occur within FOV that is exposed. [76,77].

CBCT machines employ a cone-shaped beam & a reciprocating solid-state flat panel detector, completing a single rotation around the patient to capture data encompassing the defined anatomical volume, distinct from the slice-by-slice approach of conventional CT. This streamlined process minimizes absorbed X-ray dose [78].

Scanning times for CBCT equipment vary among manufacturers. Instantaneous transmission of captured 2D images to the computer enables reconstruction into an anatomical volume for viewing across axial, coronal, and sagittal planes, facilitated by Digital Imaging & Communications in Medicine (DICOM) format compatibility, facilitating seamless telecommunication & interoperability with third-party imaging software [79].

Central to CT imaging in the computational domain is 3D image reconstruction. Mainstream CBCT scanners historically relied on traditional analytical reconstruction algorithms, although iterative reconstruction algorithms are increasingly favored for their potential in enhancing image quality and mitigating artifacts [80, 81

FOV options in dental & maxillofacial CBCT systems exhibit variability in dimensions, contingent upon detector specifications, beam projection geometry, and beam collimation capabilities [82]. FOV selection, along with voxel size, represents a pivotal determinant affecting patient radiation exposure and image fidelity, warranting careful consideration aligned with the clinical task at hand [83].

➢ *Advantages of CBCT.*

X-ray beam control: CBCT machines offer the capacity to precisely collimate the primary X-ray beam to the desired area by modifying the Field of View (FOV), thereby reducing the irradiated area. This targeted approach not only minimizes Excessive patient exposure but also reduces scattered radiation, which could otherwise compromise image quality. CBCT units are categorized based on the maximum FOV obtained from the scan or scans [84].

Radiation dosage in CBCT ranges from 29-477 μSv [85], contingent upon factors such as the CBCT equipment category, model, and FOV. Compared to conventional CT imaging for oral and maxillofacial applications, CBCT achieves substantial radiation reductions [86].

Specialized display modes for maxillofacial imaging: Furthermore, presenting interconnected images in orthogonal planes, CBCT data sets can be segmented nonorthogonally (Multi Planar Reformating), offering oblique and curved planar reformation (distortion-free simulated panoramic images), as well as serial cross-sectional reformation. These modalities enhance the delineation of precise anatomical structures and diagnostic capabilities, crucial for the intricate oral & maxillofacial anatomy. Measurements performed on-screen are free from distortion & magnification. Moreover, comprehensive 3D visualization of the dataset, including ray sum, Maximum Intensity Projection (MIP) 3D computer-generated models, is achievable [87].

Minimized image artifacts: Advanced artifact suppression techniques, coupled with an increased number of projections, contribute to minimal metal artifacts, this is especially apparent in secondary reconstructions that are designed to expose the teeth and jaws. [88].

Enhanced image precision: CBCT machines yield isotropic voxels, uniform in all three dimensions, i as opposed to the anisotropic voxels that are observed in conventional CT. Although CT voxels can have surfaces measuring as little as 0.625 mm square, their typical depth ranges from 1-2 mm. In contrast, CBCT attains submillimeter resolution, which falls within range 0.4 mm to 0.09 mm. The sub-millimeter resolution of CBCT satisfies the precision criteria for maxillofacial and oral applications. facilitating precise assessments for implant site evaluation and orthodontic analyses [89].

➢ *Limitations of CBCT:*

CBCT has swiftly gained traction in dentistry, yet it faces limitations stemming from its cone-beam projection geometry, detector sensitivity & contrast resolution, all of which contribute to artifacts, noise, and diminished image quality [78].

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A visual structure that is observable in reconstructed data but is absent in the object under examination is referred to as an image artifact. Differences between the simplified mathematical assumptions used for 3D reconstruction & the actual conditions of the measurement setup, including technical aspects of the CBCT scanner & the properties of the object under examination, give birth to these artifacts. [90].

Beam hardening, a prevalent source of artifacts, occurs when the mean energy of an X-ray beam gets higher. as it traverses an object due to differential absorption of photons. Highly absorptive materials, such as metal, act as internal filters, leading to artifacts like streaks & cupping band or dark among dense objects in the image [91, 92]. To mitigate beam hardening effects, it is advisable to limit FOV during scanning, especially in areas prone to beam hardening, such as metallic restorations or dental implants. This is achievable. through collimation, adjusting patient positioning, or separating dental arches. Manufacturers employ various strategies like, calibration correction, filtration & beam hardening correction software to minimize beam hardening [93].

Motion artifacts and misalignment artifacts are intertwined, with any misalignment among the X-ray object, source & detector leading to errors in the back projection process. Artifacts of misregistration may result from patient motion., causing blurriness in reconstructed images. Employing head restraints and conducting scans promptly can mitigate such unsharpness [94, 95].

Image noise manifests as random fluctuations in voxel values within an image, arising from multiple sources such as quantum noise from X-ray interactions and electronic noise from detector signal conversion and transmission [68]. Noise in CBCT images compromises low contrast resolution, impeding the differentiation of low-density tissues and reducing segmentation efficacy [96].

While dental CBCT excels in spatial resolution, boasting voxel sizes typically < 100 µm, its low-contrast resolution remains a challenge. Issues like scattered radiation, streak artifacts from metal surfaces, and beam hardening contribute to diminished contrast in reconstructed images. Truncation effects, stemming from FOVs smaller than the surrounding anatomy, further degrade low-contrast resolution in CBCT. These effects result from signal losses induced by structures beyond the FOV, appearing as contrast discrepancies in reconstructed images. Despite these challenges, advancements in scanner hardware and reconstruction algorithms offer prospects for mitigating low soft-tissue contrast, thus enhancing CBCT's diagnostic utility [76].

IV. APPLICATIONS OF CONE BEAM COMPUTED TOMOGRAPHY IN SOFT TISSUE THICKNESS EVALUATION

The utilization of CBCT in dental imaging for precise linear dental & hard tissue measurements has garnered significant attention in recent years [97] However, a drawback of CBCT is limited applicability in the evaluation of delicate tissues as a result of its low resolution., contrast issues, difficulty in distinguishing margins, primarily attributed to the slight density disparity between oral mucosa and air [97]. To address this limitation, various techniques and methods have been devised. Figures (1-3) show different approaches for using CBCT in soft tissue assessment.

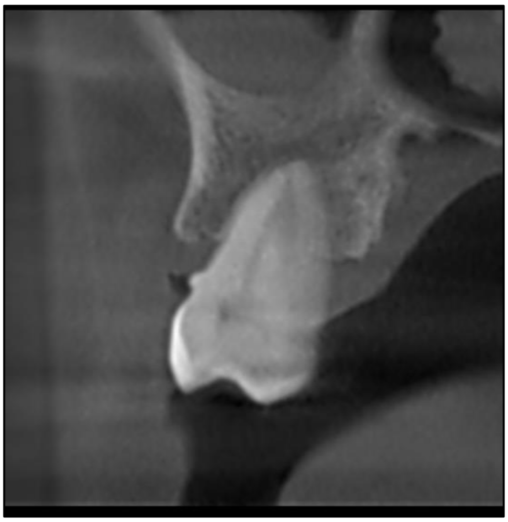

Fig 1 CBCT Cross-Sectional cut Showing that the Inferior Tongue Position makes it Clear to Identify the Palatal Soft Tissue

- Note the effect of poor soft resolution of CBCT on the ability to differentiate between labial mucosa and the cheek.

Fig 2 The use of a Cotton Rolls to Displace the Lip so that the Dental Labial Soft Tissue can be Evaluated

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Fig 3 Registration of Cast Scan on CBCT so that the Cast hint (Green) Aids in the Differentiation between the Tongue and the Palatal Mucosa. Also, it Aids in the Differentiation between the Labial Mucosa and the Cheek Mucosa.

In 2008, a noninvasive approach known as ST-CBCT was introduced to assess the dimensions & relationships of the dentogingival unit [98]. This method involves retracting the patient's lips and tongue, allowing clear visualization of facial & lingual gingiva and facilitating determination of the dentogingival unit's dimension [99]. Additionally, ST-CBCT can reveal hard tissue structures, enabling assessment of relationships between gingiva and hard tissues [100].

A study in 2019 proposed a digital workflow for crown lengthening, utilizing CBCT scans, intraoral scans to design a surgical guide digitally [101]. This technique aids in predicting the position of the gingival margin & the need for osteoplasty, enhancing the accuracy of crown lengthening procedures [101].

An innovative method combining optical 3D and CBCT images was introduced in order to achieve thorough visualization and accurate assessment of the thickness of oral soft tissue. [102]. By superimposing 3D models obtained from CBCT imaging and intraoral scanning, soft tissue thickness could be visualized and evaluated accurately without invasive procedures [102].

One recent study assessed the precision of employing CBCT for the direct measurement of mucogingival tissue thickness., employing a position-registration technique with an opaque agent [97]. Results indicated that direct thickness measurements of palatal mucosa using CBCT images can be accurate, although measurements in other locations may be slightly exaggerated [97].

Furthermore, a novel technique demonstrated the consistent determination of palatal mucosa dimensions using high-quality CBCT images obtained by retracting lips and cheek [103]. Another study in a Japanese population employed CBCT to comprehensively analyze palatal mucosal thickness and its association with palatal vault depth, suggesting the utility of CBCT in minimizing surgical complications [104].

In 2019, a study investigated the accuracy of measuring palatal mucosa thickness using CBCT & developed a conversion formula for more precise evaluation [105]. This research highlighted the usefulness of CBCT to precisely and noninvasively measure the thickness of the palatal mucosa [105-144].

V. CONCLUSION

This review has extensively covered the advancements in the evaluation and treatment of palatal masticatory mucosa, with a particular focus on the thickness of the palatal mucosa and its implications for periodontal & peri-implant surgeries. Utilization CBCT has emerged as in regard to significance advancement in accurately assessing palatal mucosa thickness, despite its limitations in resolution and contrast for soft tissue visualization. Innovations and methodologies have been devised in order to overcome these limitations. enhancing the predictability and outcomes of mucogingival surgeries.

The evolution of mucogingival surgery, from its inception to the current state of periodontal plastic surgery, underscores the importance of addressing mucogingival anomalies for both aesthetic and functional outcomes. The classification systems for marginal tissue recession and soft tissue grafts have been refined to better predict surgical outcomes and guide treatment planning. The review highlights the critical role of KT in maintaining periodontal & peri-implant health, challenging the notion that the absence of attached gingiva necessarily leads to adverse outcomes in well-maintained oral hygiene conditions.

Soft tissue grafting techniques, particularly using of autogenous grafts, have been emphasized for their reliability in enhancing keratinized tissue width and thickness. The review discusses the advantages and limitations of various grafting materials, including autogenous, allogeneic, and xenogeneic grafts, in achieving desired clinical outcomes. The shift towards using CTG over FGG reflects the ongoing advancements in periodontal plastic surgery aimed at optimizing esthetic results.

In conclusion, the review underscores the significance of a thorough understanding of the palatal masticatory mucosa's anatomy, histology, and the various surgical techniques available for managing mucogingival deficiencies. The advancements in diagnostic and surgical techniques, coupled with a deeper understanding of tissue biology, have significantly improved the predictability and aesthetics of periodontal and peri-implant surgeries. Future research should continue to explore innovative materials and techniques to further enhance t Results obtained from mucogingival surgery and address the challenges associated with soft tissue management around implants & teeth.

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