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3D PALATAL SOFT TISSUE ANALYSIS: A PILOT STUDY

Dissertação apresentada à Universidade Católica Portuguesa
para obtenção do grau de Mestre em Medicina Dentária

Por:
Riccardo Corsi

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Por: Riccardo Corsi

Orientador: Professor Doutor Tiago Miguel Santos Marques
Co-Orientador: Professor Doutor Danilo Fernandes
Co-Orientador: Mestre Filipe Araújo

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QUOTE

"Aut invenium viam aut faciam"

(Annibale)

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Thank you to my co-authors for their support, advice, and complicity in the realization of my thesis. I thank them for giving me the opportunity to work in an interesting and dynamic environment, which allowed me to get involved and gain valuable experience for my future.

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Ai miei nonni!

ABSTRACT:

Background: Periodontal diseases, including gingivitis and periodontitis, significantly affect oral health and are influenced by various factors. Traditional methods of diagnosis and treatment, limit the effectiveness of interventions. The adoption of advanced digital technologies, like intraoral scanners, 3D imaging (CBCT) and AI, has transformed periodontology, enabling more accurate diagnoses, precise planning, and effective disease management. A detailed understanding of periodontal anatomy, especially of the palatal mucosa and neurovascular bundle position, is crucial for successful surgery. Integrating these technologies with sound anatomical knowledge fosters the development of innovative therapies, improving clinical outcomes.

Materials and methods: CBCT bone models (STL files) and 3D impression models (PLY files) of the upper jaw were prepared for 49 patients, 51% of whom were women. The study measured the palatal mucosal thickness (PMT) in the palatal region (ROI 1-4), analyzed parameters of the palatal artery (PA), palatal depth (PD), great palatal foramen (GPF) and the palatal angle (Pang). The models were loaded into coDiagnostiX® and Geomagic® software for the evaluation. Patients were identified with clinical process numbers to maintain anonymity.

Results: The study showed that men had a higher average PMT than women in several measurements. A weak but significant correlation was found between age and certain mucosal thickness parameters, while no significant correlation emerged between age and palatal artery position. Differences in PD between sexes were found to be statistically significant.

Conclusions: This study revealed that male subjects had significantly higher mean values in PMT than females, with greater palatal depth and maximum size. Palatal angle was stable between the sexes, while GPF position remained constant. There were no significant differences in PA variables between sexes and age groups. These results underscore the importance of considering sexes and age to improve the accuracy of dental treatment.

Keywords: Periodontics, Palate, Digital, Vascular measurements, Foramen, Mucous membrane.

RESUMO:

Introdução: Doenças periodontais, incluindo gengivite e periodontite, afetam a saúde bucal e são influenciadas por diversos fatores. Métodos tradicionais de diagnóstico e tratamento limitam a eficácia das intervenções. A adoção de tecnologias digitais, como scanners intraorais, imagem 3D (CBCT) e IA, transformou a periodontologia, permitindo diagnósticos mais precisos, planejamento exato e gestão eficaz das doenças. Um entendimento detalhado da anatomia periodontal, especialmente da mucosa palatina e da posição do feixe neurovascular, é crucial para o sucesso cirúrgico. Integrar essas tecnologias com um conhecimento anatômico sólido promove o desenvolvimento de terapias inovadoras.

Materiais e métodos: Modelos ósseos de CBCT (arquivos STL) e modelos de impressão 3D (arquivos PLY) da mandíbula superior foram preparados para 49 pacientes, dos quais 51% eram mulheres. O estudo mediu a espessura da mucosa palatina (PMT) na região palatina (ROI 1-4), analisou parâmetros da artéria palatina (PA), profundidade palatina (PD), forame palatino maior (GPF) e o ângulo palatino (Pang). Os modelos foram carregados no software coDiagnostiX® e Geomagic® para a avaliação. Os pacientes foram identificados com números de processo clínico para manter o anonimato.

Resultados: O estudo mostrou que os homens tinham uma PMT média maior do que as mulheres em várias medições. Foi encontrada uma correlação fraca, mas significativa, entre a idade e certos parâmetros de espessura da mucosa, enquanto não houve correlação significativa entre a idade e a posição da artéria palatina. Diferenças na profundidade palatina entre os gêneros foram consideradas estatisticamente significativas.

Conclusões: Este estudo revelou que os sujeitos masculinos tinham valores médios significativamente maiores de PMT do que os femininos. O ângulo palatino foi estável entre os sexos, enquanto a posição do GPF permaneceu constante. Não houve diferenças significativas nas variáveis de PA entre os sexos e grupos etários. Esses resultados destacam a importância de considerar gênero e idade para melhorar a precisão do tratamento dentário.

Palavras-chaves: Periodontologia, Palato, Digital, Medidas vasculares, Forame, Membrana mucosa.

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List of abbreviation and acronyms

AI: artificial intelligence

FGG: free gingival graft

GF: gingival graft

GPA: great palatal artery

GPF: great palatal foramen

LP: lamina propria

PA: palatal artery

PD: palatal depth

PMT: palatal mucosa thickness

SM: submucosa

CBCT: Cone Beam Computed Tomography

Meandist: mean distance

Mindist: minimum distance

Maxdist: maximum distance

PA_CPM1 (ROI-1): palatal area from the canine to the first premolar

PA_PM1PM2 (ROI-2): palatal area from the first premolar to the second premolar

PA_PM2M1 (ROI-3): palatal area from the second premolar to the first molar

PA_M1M2 (ROI-4): palatal area from the first molar to the second molar

PA_CPM1(2): palatal area from the canine to the first premolar

PA_PM1PM2(2): palatal area from the first premolar to the second premolar

PA_PM2M1(2): palatal area from the second premolar to the first molar

PA_M1M2(2): palatal area from the first molar to the second molar

(2): 2^{nd} quadrant

Pang: Measurement of the palatal angle and reference points on the image of the second molar level

PD: Measurement of the palatal depth according to the distance between the center of the mid palatal suture and the line of the distance between the second molars

D_2MJEC: Measurement of the distance between the second molars, at the level of the cement enamel line

GPF_PACM: Measurement of the apex-coronal distance from the path of the GPA to the CEJ of the second molar

GPF_PRT: Measurement of the distance between the position of the GPF in relation to the teeth

D GPF_MS: Measurement of the distance between the GPF and the median suture

D GPF_IIF: Measurement of the distance between the GPF and the inter incisional foramen

NCD: chronic noncommunicable disease

PPS: periodontal plastic surgery

DICOM: Digital Imaging and Communications in Medicine

ROI: Region of interest

JEC: cementoenamel junction

1. Introduction

1. Introduction

1.1 Periodontology as an area of dentistry

In recent years, advances in digital technology and new discoveries have significantly transformed diagnostic and therapeutic practices in the field of dental medicine (1). The periodontium is a dynamic structure and therefore can be subject to changes and different therapeutic interventions which may differ from patient to patient (2).

The periodontium, which refers to the supporting and covering tissues of the tooth, includes the root cementum, the periodontal ligament, the alveolar bone surrounding the dental socket and the marginal gingiva that directly contacts the tooth in the region of the tooth gingival junction (3). The integrity and functionality of the periodontium is essential for maintaining oral homeostasis and preventing periodontal disease (2).

Periodontology is a fundamental discipline in Dental Medicine field, it focuses on maintaining the health of the supporting tissues of the teeth (4). The definition of periodontal health is a crucial element in establishing a point of convergence in the assessment of periodontal disease and in meaningfully delineating treatment outcomes (5).

Periodontal health is defined as the absence of disease or inflammation, assessed clinically, and considers the natural immune response with reference to levels of biological and inflammatory markers consistent with a state of balance between hard and soft tissues (2). When periodontal homeostasis is compromised, periodontal diseases can occur (3).

Gingivitis is an inflammation of the gums, commonly induced by the accumulation of bacterial plaque (3). Clinical signs of gingivitis include gingival erythema, edema, and gingival bleeding, particularly evident during oral hygiene such as brushing or flossing. Gingivitis is a reversible form of gingival inflammation that, if left untreated, can progress to periodontitis, a more serious condition involving inflammation and loss of periodontal tissues, including gingiva, periodontal ligament, and alveolar bone (3).

Periodontitis is a chronic noncommunicable disease (NCD) that shares social determinants and risk factors with major NCDs, such as cardiovascular disease, diabetes, cancer, and chronic respiratory disease, which are responsible for about two-thirds of deaths worldwide (6). Periodontal diseases, which include gingivitis and periodontitis, are among the most prevalent oral conditions (7). Periodontal diseases are closely related to several factors, along with the presence of bacterial plaque, genetic predisposition, stress, and poor oral hygiene (3). The risk of developing periodontitis has been linked to smoking, obesity, inadequate diet (both in terms of caloric intake and nutrient quality) and lack of physical activity (7).

Microbiological, environmental, and host factors are among the 3 main factors that contribute to the emergence of the changes that lead to periodontal disease (8). Precisely because of this, periodontal diseases can no longer be considered as simple bacterial infections, i.e., caused by a single factor, but as a set of factors that predispose the patient to these diseases (2). Thus, the definition of periodontal disease is a multifactorial condition originated from a complex interaction that is created between the subgingival microbiota, i.e. the accumulation of plaque and thus bacteria in the subgingival space, the immune responses that our organism makes as a first attempt at defense with consequent inflammatory responses and modifying environmental factors (9).

These risk factors not only contribute to the pathogenesis of periodontitis, but also influence the body's response to treatment and healing (8). Interactions between genetic, environmental, and behavioral factors play a crucial role in the onset and progression of the disease, necessitating integrated and multidisciplinary management to effectively prevent and treat this condition (7). However, modifying the structure and position of the periodontium is not a trivial process and may entail risks of compromising the structure and health of the periodontal structure itself. In this context, the intersection of different dental disciplines, together with various therapeutic strategies, plays a crucial role in preventing such problems.

Prevention and early treatment of periodontal diseases are essential to preserve the health of the periodontium and prevent associated systemic complications such as heart disease and diabetes (10). The handling of periodontal tissues plays an important role in the therapeutic approach to periodontal disease when conventional methods and non-surgical treatments do not prove effective in resolving the pathological conditions in question (11). In these circumstances, there is a need for a more invasive and targeted intervention that can address the advanced manifestations of periodontal disease and promote health and integrity recovery of compromised periodontal tissues.

The clinical management of periodontal disease represents a significant global challenge, and the regeneration of periodontal tissue defects due to periodontitis is one of the major challenges in regenerative dentistry. Although conventional therapies, mainly focused on controlling inflammation, can slow or stop disease progression, complete regeneration of periodontal tissue remains a complex and ambitious goal (7).

Lack of mucosal adherence has been correlated with a significant increase in dental plaque accumulation, a greater tendency to mucosal inflammation, an increased likelihood of developing soft tissue recession defects and an overall difficulty in implementing adequate patient maintenance therapy (4).
Therefore, periodontal health should not only be considered in the context of levels and control of plaque and bacteria but should include a holistic consideration and evaluation of all factors responsible for the onset of disease as well as the restoration and maintenance of health (9).

To achieve this goal, good oral hygiene, good patient compliance, and conscientious work by the dentist must be the cornerstones of primary treatment. Achieving periodontal stability is imperative to be able to create areas for graft implantation and to be able to have overall healthy stability of the oral cavity. Gingival and bone attachment loss, together with the complex impairment of periodontal tissue integrity, can contribute to root exposure, tooth sensitivity, carious and non-carious lesions in the cervical region of teeth, generated by gingival recessions, as the predisposing factor, and can be predicted and treated in time (12).

To address this problem, several periodontal plastic surgery approaches and materials have been created, including free gingival grafts, subepithelial connective tissue grafts, acellular dermal matrix grafts and guided tissue regeneration (13).

These procedures require a high degree of knowledge of the anatomy of the palatal soft tissues and the structures involved.

1.2 Anatomy of palatal soft tissues

The gingival tissue of the maxilla in the palatine area is a fundamental part of the periodontium, providing support and protection to the upper teeth due to its anatomical and histological structure specifically adapted to perform support and defense functions (14). The oral gingiva plays a role in sensory perception within the mouth and in the absorption of micronutrients, in addition to its protective function (2).

The mucosa of the human hard palate is organized in three distinct layers. The first layer consists of the keratinized stratified pavement epithelium, followed by the papillary layer of the lamina propria (LP). These two layers combined constitute the masticatory mucosa. Beneath them lies the submucosa (SM), a lax support structure predominantly composed of adipose tissue (15).

The palatal mucosa is characterized by a thick, well-developed ortho keratinized squamous epithelium with occasional areas of para keratinized epithelium, evidenced by the presence of conserved nuclei in the keratinized cells, important because the palate is subjected to mechanical forces during chewing (15). Gingival connective tissue, also known as LP, is mainly composed of collagen fibers, cells, and physiological substance. Among the various cells present are fibroblasts, mast cells, macrophages, and inflammatory cells. Fibroblasts are the predominant cell population, responsible to produce collagen fibers and the basic substance of connective tissue. Collagen, in turn, plays a crucial role in ensuring the structural integrity of gingival tissue (14).

Mucogingival defects, including a lack of keratinized tissue and gingival connective tissue, are common problems. The absence of keratinized tissue around teeth is considered a predisposing factor for the development of gingival recessions and/or inflammation. The presence and health of gingival connective tissue plays a significant role in maintaining gingival stability and health (14).

In the field of soft tissue replacement surgery, it is crucial to acquire a thorough knowledge of the histology of the donor site, as well as to understand the complex processes of integration and revascularization of the transplanted tissues, allowing for greater predictability and success in the treatment of soft tissue defects (15).

1.3 The importance of palatal soft tissue in dental treatments

Carefully examining the characteristics of soft tissue plays a crucial role in the overall definition of aesthetic outcomes of various treatments, spanning areas such as periodontal plastic surgery, dental implants, and prosthetic and restorative procedures (16). Consideration of this clinical aspect takes on relevance when the aim is to achieve optimal aesthetic results, especially in the delicate buccal aspect (17).

To ensure an effective treatment with optimal results, the evaluation of gingival dimensions plays a fundamental role in treatment protocols for periodontitis, dental restorations, implants, and orthodontics (18).

Soft tissue grafting procedures, aimed at increasing mucosal thickness, have been effectively used to correct soft tissue volume deficiencies around teeth, especially in conjunction with immediate implants (18). Numerous evidence indicates that implant placement, coupled with simultaneous bone grafting, must be complemented with a soft tissue grafting procedure (19). This synergistic approach is crucial to counteract the processes of post-operative contouring and remodeling, in particular, the addition of a subepithelial connective tissue graft has been shown to significantly improve aesthetic appearance, as assessed by the pink aesthetic score, and to reduce the likelihood of mid-facial soft tissue recession (20).

Analysis of the thickness and extent of keratinized gingival tissue remains one of the most crucial factors for aesthetic appearance, functionality, and soft tissue health preservation surrounding both natural teeth and dental implants (17).

Effective soft tissue management in clinical periodontology is essential for maintaining dental stability and achieving optimal esthetic outcomes (4).

Modern technology has provided us with diagnostic assessment tools to get more detailed information, allowing us to reproduce sections of the oral cavity and/or generate a three-dimensional image of the oral cavity by means of radiation acquired by a digital sensor and processed by a computer (16). Especially in the field of oral tissue regeneration and in the field of surgery, it is becoming essential to obtain this detailed information.

1.4 Effectiveness of soft palatal tissue management in clinical periodontology

Periodontal Plastic Surgery (PPS) is a specialized area of periodontology that focuses on the prevention and correction of defects in the gingival mucosa, alveolar bone and surrounding bone tissue caused by a variety of factors, including abnormalities, trauma, and periodontal disease (21).

This field of dental surgery aims to restore the health and aesthetics of gum and bone tissue, improving the functionality and aesthetic appearance of the smile. Periodontal surgical procedures may include bone reconstruction, soft and hard tissue grafting, sinus lift and other advanced techniques aimed at regenerating and reconstructing damaged tissue (21).
Effective soft tissue management in clinical periodontology is essential for maintaining dental stability and achieving optimal aesthetic outcomes (4).

Periodontal diseases, such as gingivitis and periodontitis, result in chronic inflammation of the gums and progressive loss of bone tissue around the teeth, leading to gum recession, tooth mobility and, in severe cases, the loss of the teeth themselves. Periodontal plastic surgery offers customized solutions to treat these conditions, restoring periodontal health and improving the patient's quality of life. The surgical techniques used in PPS are based on advanced scientific and clinical approaches that consider the specific needs and anatomical characteristics of everyone (21). This customized approach guarantees optimal and long-lasting results, allowing patients to enjoy a healthy, functional, and aesthetically pleasing mouth (22).

1.5 Importance of clinical evaluation of palatal soft tissue in periodontal treatment

The palatal masticatory mucosa is widely used as donor tissue in periodontal plastic surgery for root coverage procedures, to increase the width of the attached gingiva and for alveolar ridge augmentation (23). Palatal mucosal thickness (PMT) analysis emerges as a highly recommended practice to be performed prior to surgery, as it can directly impact the surgery planning strategy itself. Its targeted execution aims to maximize both the width and thickness of the graft, thus ensuring optimal harvesting from the appropriate area (24).

Identifying the location and nature of periodontal issues is crucial for determining the appropriate starting. Clinical assessment of palatal soft tissue thickness and bone depth is imperative for accurate diagnosis and treatment planning, particularly before surgical, resection, or regenerative interventions, when it comes to rehabilitating areas requiring gingival grafts (GF) (25).

A soft tissue graft taken from the palate with the overlying epithelium is called a free gingival graft (FGG), this type of graft was first introduced with the aim of increasing the amount of keratinized tissue that is missing or lost (22). Free gingival grafts are often used in dentistry to treat gingival recessions, improve smile aesthetics, and function, and stabilize the gingival margin around teeth or dental implants(26).

The procedure consists of harvesting a small fragment of tissue from the palate, which is then transplanted into the recipient area to increase the amount of keratinized gingiva required, thereby significantly improving the patient's overall oral health, decreasing tooth sensitivity, and protecting exposed tooth roots (22).

The thickness of the soft tissue graft is a key element in the survival of the graft itself, the healing pattern, and the clinical outcome of mucogingival surgical procedures (27).

Accurately measuring the thickness of the mucosa at the beginning of the surgical procedure is crucial to maximize both the width and the thickness of the graft, obtaining them from the most suitable area (24).

The size of the tissue harvested from the donor site is important in determining the most suitable treatment and anticipating the post-operative course, also, acquiring an accurate knowledge of the thickness of the palate would guide the periodontist in making appropriate incisions and selecting the most appropriate site to obtain a graft of the right size and consistency (28). Several factors are believed to influence palatal gingival thickness, including age, sexes, ethnic group, smoking habits, dental conditions, orthodontic treatment, systemic diseases, drug intake, immunosuppression status, and individual variations (27).

1.6 Palatal soft tissue measurements

These measurements can be conducted either directly or indirectly. Precision in clinical decisions and the attainment of optimal aesthetic outcomes hinge significantly on the measurement of periodontal soft tissue (22). Autologous connective tissue stands out as an indispensable therapeutic resource in mucogingival periodontal surgery, addressing both functional and aesthetic considerations (28).

The success of gingival grafts is highly dependent on their adequate thickness and the quality of the donor site (29). The main donor sites for connective tissue grafting are the palatal area, the area of the maxillary tuberosity and edentulous sites; knowing these donor sites anatomically will increase the probability of successful surgery, due to the histological similarities and features between the gingiva and these areas (23,24).

As the palatal mucosa is the preferred site for autogenous tissue harvesting compared to other regions, it is commonly used in periodontal mucogingival surgical procedures (29). This preference is also reflected in its main role in providing a mucoperiosteal flap during surgery to treat oro-antral fistula and cleft palate, being rich in connective tissue and blood vessels optimal in tissue healing and regeneration (24).

To accurately measure the thickness of the palatal mucosa, perforation of the tissue is sometimes performed with a periodontal probe under local anesthesia; however, these methods, although effective and reliable, are invasive and may result in an incorrect measurement due to the complex anatomy of the dental arch and palatal plane, as well as the various periodontal alterations (23).

According to Rashidat Ul Khairat “Assessment of thickness of palatal mucosa by periodontal probe, is commonly performed immediately prior to surgery as the patient must be anaesthetized and may hinder appropriate treatment planning of the procedure as the clinician may find that there is not sufficient tissue thickness in the pre- anaesthetized area thus not allowing a precise pre- surgical planning of the procedure” (30).

Unfortunately, the daily clinical analysis of periodontal tissues mainly offers information regarding the general health status and the presence of inflammation. Specific bone loss and gingival thickness present by far a more complex diagnostic procedure (16).

As an alternative, it is feasible to conduct indirect, trauma-free evaluations by analyzing sectional images of three-dimensional radiographs, compared with three-dimensional tissue representations obtained through an intraoral scanner that generates a 3D copy of the oral soft tissues. Obtaining detailed information regarding the thickness of different regions of the palatal mucosa is of considerable interest for various therapeutic and rehabilitation approaches in the oral cavity. Such in-depth knowledge is crucial for optimizing intervention strategies in diverse therapeutic and oral rehabilitation contexts (23).

1.7 Critical considerations on soft tissue graft harvesting

During periodontal surgery procedures in the palatal area, it is crucial that dentists pay special attention to the collection of graft material. In addition to evaluating the mucosal thickness, a factor of utmost importance is a detailed understanding of the location and route of the palatine artery, and all the anatomical structures involved in this area.

The great palatine artery (GPA), a branch of the facial artery, plays a vital role in the vascularization of the palate region and adjacent structures. Its location and pathway can vary greatly between individuals, emphasizing the importance of a precise, individual assessment prior to any surgical procedure (31).

A thorough anatomical knowledge of the GPA is essential to avoid complications during periodontal procedures, such as the risk of bleeding and vascular damage. Therefore, it is essential that dentists perform a complete and accurate evaluation of the palatine artery before proceeding with any surgical procedure in the palatal area (32).

The arterial supply of the palate in its anatomy-clinical complexity is an area of great interest and relevance in maxillofacial surgery and dentistry. Among the vascularized structures in the palatal region, the greater palatine artery emerges as the main vessel responsible for the blood supply to the hard palate, while the ascending palatine artery assumes a prominent role in ensuring blood flow to the soft palate (31).

These arteries, critical branches of the facial artery, are crucial for the maintenance of tissue viability and the effective healing of surgical procedures in the palatal region. The greater palatine artery, with its intricate course through the soft tissue and support of the hard palate, provides a crucial blood supply to ensure the survival and function of the anatomical structures involved (32).

It descends, together with its nerve, through the greater palatine canal, emerging on the lower surface of the hard palate through the Great Palatal Foramen (GPF), usually located near the midpalate aspect of the third molar (29).

On the other hand, the ascending palatine artery, with its route through the soft tissue of the soft palate, assumes an equally crucial role in ensuring perfect vascularization and, consequently, the vitality and healing capacity of the structures involved (33).

The GPF, or greater palatine foramen, represents a crucial anatomical feature in the palatal region, playing a key role in periodontal surgery and in understanding the course of the palatine artery (32).

This foramen, located in the posterior part of the hard palate, forms the passageway through which the greater palatine artery and the poster-superior palatine nerves enter the palate. Its location and size may vary between individuals, and a detailed knowledge of these variations is essential to avoid damage to blood vessels and nerves during surgical procedures (33).

In the context of periodontal surgeries, understanding the location and size of the GPF is crucial to accurately plan surgeries and minimize the risk of blood vessel and nerve damage during manipulation of surrounding tissues, its accurate identification can facilitate the harvesting of bone grafts or the placement of dental implants, optimizing the clinical outcomes of surgical procedures (34).

Furthermore, knowledge of the course of the GPA through the GPF is of paramount importance to avoid vascular complications during surgical procedures in the palatal area. Incorrect manipulation of the surrounding tissues could result in damage to the palatine artery and subsequent hemorrhagic problems or impairment of the tissue vasculature (34).

A thorough understanding of the anatomy and distribution of these arteries in the palatal region, in the position of the GPF, is essential for the successful planning and execution of surgery, while minimizing the risk of vascular complications and optimizing clinical outcomes for patients undergoing surgical procedures in this delicate region (29).

In addition, research into surgical approaches that minimize the risk of damage to the palatine artery, such as the use of graft material harvesting techniques that preserve the local vasculature, may help to improve clinical outcomes, and reduce post-operative complications (34).

This is where new technological breakthroughs and diagnostic approaches step in.

1.8 The evolution from Conventional to Digital Dentistry

Conventional dentistry involves traditional techniques and tools that have been used for decades. These techniques include creating oral models and oral molds using materials such as alginate, silicon, and gypsum to create reproduction of teeth and gums (35). The same paper records of patients, medical and anamnestic patient records kept in physical archives. All this incorporates the daily routine of most dental clinics (35).

Toward the end of the 20th century, with the introduction of 2D imaging, the diagnosis and treatment of various maxillofacial structures had implications never thought of until then, remaining to this day the standard examination of reference for dentistry.
While being the empirical examination of dentistry being a 2D examination provides crucial but somewhat limited information when it comes to periodontal health or treatment options in cases of grafting, "rehabilitation" of soft or hard tissue.

As digital dentistry emerges, advanced technologies have been introduced that offer numerous advantages over conventional methods. Key features and benefits include using intraoral scanners to create accurate digital images of teeth and gums, eliminating the need for physical dental impression, which can be lost or damaged, and offering greater patient comfort and more accurate results (36).

Digital X-rays offer high resolution images immediately available, processed by a computer in seconds, with less radiation exposure compared to traditional methods.

Technological progress has provided innovative tools that revolutionize diagnosis and allow more accurate prediction of treatment in the various areas of dentistry.
Three-dimensional (3D) modelling technologies have opened revolutionary new perspectives in the analysis and management of anatomical structures, soft and hard tissues within the oral cavity (37).

The transition from conventional to digital dentistry brings significant improvements in terms of precision, efficiency, and patient comfort. Although traditional methods have their merits and remain in use, digital technologies are increasingly becoming the standard in modern dental practices (36).
These technologies provide innovative tools for precise diagnosis, advanced treatment planning and effective communication with patients (37). Effective communication since the same patient can digitally observe the reproduction of his or her mouth and possibly access his or her own data entered the software, significant reduction in patient waiting times, greater efficiency in the production and customization of dental devices, digital documentation collection, with the possibility of merging clinical history and study material in the same file, having better data management and integration with other healthcare systems (35).

Using these new technologies, specialists will be able to have detailed information about the measurements and localization of the anatomical structures of the palatal area (38).

1.9 The Role of 3D Technologies in Soft and Hard Tissue Analysis

Exploring the application of 3D technologies in soft and hard tissue analysis of the oral cavity, with a focus on periodontology, is one of the reasons why the use of intraoral scanner and CBCT (Cone-beam computed tomography) should be investigated and improved.

CBCT is a biomedical imaging technique that uses cone-shaped X-rays. This technique involves a scanner that rotates around the patient's skull and acquires approximately 600 separate images, allowing a detailed scan of the structures being analyzed. CBCT technology as well as intraoral scanners offer dental professionals high-precision, high-quality 3D diagnostic images, making them indispensable diagnostic tools for dentistry today (27).

However, as documented in recent years, the evaluation of periodontal soft tissues, gingiva, and oral mucosa, using CBCT has been complex due to the poor contrast presented by oral soft tissues, except for the palatal mucosa, which, being closer to the air, is better defined and easier to evaluate (38).

The intraoral scanner represents another major 3D innovation at the technological level. This new technology allows us to have, in a short time and in a completely safe and rapid manner, a 3D digital copy of all the structures of the oral cavity. These digital reproductions of oral tissues are used to prepare and study treatment plans. It can be used in many fields of dentistry including orthodontics, fixed prosthodontics, and periodontics.

Three-dimensional soft tissue analysis not only allows the evaluation of post-operative results, but also offers the possibility to monitor the evolution of periodontal disease over time. To obtain accurate visualization of soft tissue, hard tissue and teeth, preoperative data usually include a CBCT scan and intraoral surface recording or digitized model (12,21).

Although the crucial importance of palatal mucosal thickness assessment in perfecting predictions regarding the outcome of various surgical procedures is moving in the right direction, the initial phase of thickness examination in the donor area is often overlooked and overestimated, mainly due to the lack of reliable methodologies for this specific purpose.

Another advantage of new technologies is the introduction of artificial intelligence (AI) in dentistry. It refers to the use of machines and technologies to perform tasks that normally require human intervention, by designing an intelligent computer system that displays characteristics associated with intelligence in human behavior, such as understanding language, learning, reasoning, problem solving and more (39).

Imaging is crucial in many areas of healthcare, and AI is particularly effective in overcoming the variability of individual subjective assessments, improving the effectiveness of care, and reducing costs by automating routine tasks (40).
Artificial intelligence can perform various simple tasks in a dental practice with greater precision, fewer staff, and fewer errors than humans. These tasks include booking and coordinating regular appointments, as well as assisting with clinical diagnosis and treatment planning (39).
The use of dental software, in combination with the AI, enables ubiquitous collection of digital health data, and although this data has been rather heterogeneous so far, organizations are increasingly striving to provide clean, curated, and structured data. Artificial intelligence also plays a key role in palatal soft tissue measurements, improving diagnostic accuracy and treatment planning through its ability to analyze complex details and provide highly accurate assessments (40).

The thickness of the palatal mucosa, not only at the specific graft site, but at a general level, provides essential information for determining the location and of soft tissue harvesting technique, thus tailoring the treatment to the patient's needs. In mucogingival periodontal procedures, the amount of palatal masticatory mucosa can play a decisive role in formulating the treatment plan and influencing surgical outcomes, in graft survival, healing mode and clinical outcome of mucogingival surgery (27,28).

CBCT is distinguished by its excellent image quality, which translates into remarkable resolution, section thickness, reduced exposure dose and minimized artefacts. Its characteristics of reliability and precision are widely documented in the analysis and diagnosis of soft and hard periodontal tissues, thus consolidating its relevant role in clinical use (38).

In brief, to optimize analysis and diagnosis by integrating information from intraoral scanners and CBCT in a rapid, detailed, and efficient manner, can be adopted the approach of combining these digital data streams. Before the dental procedure, data collection usually involves a thorough examination of the patient's medical history, with particular attention to dental history and general health status, by implementing a diagnostic scan using CBCT and an intraoral surface investigation using a digital model obtained through a 3D intraoral scanner can be performed (41,42). This methodology allows for accurate visualization of the teeth and soft tissue, thus contributing to a complete and detailed assessment prior to surgery (12).

CBCT offers the possibility to observe and measure the soft tissues of the dental gingival unit. By examining the perspectives of three-dimensional soft tissue analysis, with a focus on palatal mucosal thickness, we aim to integrate these technologies into clinical practice to improve the care of patients with periodontal disease (38).

This emerging field offers opportunities for detailed assessment of gingival tissues, their thickness, periodontal pockets, and alveolar bone loss, enabling oral health professionals to plan periodontal surgery with unprecedented accuracy and predictability.

2. Objectives

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2. Objectives

This study aims to explore the use of 3D technologies in periodontal soft tissue analysis, including scanning imaging systems, CBCT and intraoral surface models. The primary objective is to collect and utilize patient data from the Dental Clinic of the Portuguese Catholic University of Viseu. Specifically, the study aims to:

- Compare CBCT scans with data collected via intraoral scanners to conduct a comprehensive analysis of palatal mucosal thickness from the gingival margin to the mid-palatine suture in a sample of university dental clinics.
- Assess the feasibility of using these technologies to gather detailed information on the anatomical structures of the palatal area.
- Assist clinicians in diagnosis and treatment planning in clinical periodontology by improving their ability to diagnose and plan treatments using 3D tools such as intraoral scanners and CBCT.
- Predict the outcomes of dental surgical treatments or tissue regeneration related to mucosal therapy and determine the optimal location for harvesting gingival grafts.
- Assess the risks associated with surgical treatment of palatal soft tissue, including distances from the palatine artery and other favorable components.
- Understand variations in palatal soft tissue thickness as a function of age and gender and identify regions of greatest and least thickness within the palatal area.
- Measure the distances between the bony and gingival surfaces in the entire palatal region of interest, from canines to second molars, at apical distances of 3 and 8 mm from the gingival margin.
- Determine the position of the greater palatine foramen (GPF) in relation to the teeth, median suture, and incisor foramen.

Null hypothesis:

H1: There are no significant differences between the sexes in the analyzed parameters.

H2: There are no significant differences between age and average and maximum palate thickness.

H3: There are no significant differences between palate angle and average and maximum palate thickness.

The goal is to improve the oral health and quality of life of patients with periodontal disease by exploiting 3D technologies to better understand the anatomy and structures of the palatal area, facilitating more precise retrieval of gingival graft material.

3. Materials and Methods

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3. Materials and Methods

3.1 Study design and inclusion criteria

This is a pilot study, preliminary research conducted on a small scale to assess the feasibility, time, risks, and potential effects of this research, in which a 3D-level analysis (CBCT + intraoral scanner) of palatal soft tissue structures was performed.
The study included the use of descriptive and inferential statistics to analyze variations in palatal soft tissue thickness and quantity among different patients, confirmed by millimeter measurements of these dimensions, on patients at the Dental Clinic of the Portuguese Catholic University of Viseu, from 01/10/2023 to 11/06/2024.

In addition, we assessed variations in major palatine artery location and risk factors related to the collection of graft material, as well as pre-surgical evaluation and outcomes, in relation to the two parameters, soft tissue thickness and artery location.
To ensure that patient data could be used, inclusion criteria were introduced: pre-existing CBCT and intraoral scan of the upper jaw and palate, carried out within the previous 12 months, since January 2023 to January 2024; that patients don’t take medication that could cause gingival hyperplasia (anti-epileptics, immunosuppressants, antihypertensives); no history of mucogingival or bone surgery in investigation; a healthy periodontium (with periodontal pockets <4mm); palatal dentition of at least 12 teeth, no presence of metallic restauration to avoid radio-opaque images that can lead to measurement errors.

3.2 Characterization of collected data

The collected data will consist of consolidated, fully anonymized files, extracted from the university clinic software (Newsoft®), relating to clinical data and the results of 3D X-ray and scanner examinations carried out on patients who have undergone various types of treatments, where these two diagnostic means were essential in the diagnosis of each patient's diseases, over a period of each data collected will not be linked to any patient in a way to be anonymous. Data of 49 patients from the Dental Medicine Faculty – Catholic University in Viseu were obtained. 11 patients were excluded due to the impossibility of reading the collected 3D data. With this data we try achieving as a goal the possibility of using these 3D assessment technologies to gather detailed and precise information regarding the palatal soft tissues.

For this data be used, each patient present in this study must be in possession of a CBCT and an intraoral scanner of the palatal region. In addition, the differences and various anatomical details will thus be compared, based on measurements made in matching software (CodiagnostiX®(43) and Geomagic®(44)). Information acquired using oral surgery navigation software and digital workflows, combining bone models obtained by cone beam computed tomography (CBCT) with intraoral surface models, will be exploited to conduct a virtual analysis of the masticatory mucosa in the palatal region.

3.3 Data collection and analysis instruments

The thickness of the palatal mucosa, for each patient, in the study were determined, such as the palatal soft tissue variations in the various patients. As we know from various studies, gingival thickness and histological composition of the same gingiva can be individualized and different, even in the same patient.

This study involves the collection of data and its fusion with STL models, derived from CBCT Digital Imaging and Communications in Medicine (DICOM) data, combined with intraoral virtual models of palatal soft tissues, scanned in the Dental Medicine Faculty – Catholic University in Viseu using the software “3Shape Dental Software” (45).

Importing DICOM files of study patients from the computer selected source onto the CodiagnostiX® software(43), accessing patient data and being sure that we have entered the right patient data, we have created the dataset for each specific patient.

To collect these data, using the CodiagnostiX® software (43), with the help of AI assistant, we were able to put CBCT scans of bone on the software, whereas AI can only process CBCT scans. Accessing patient planning data, we have chosen the maxilla as the reference. While the AI assistant was processing the DICOM data, we imported the STL data into the AI assistant by clicking on “Load Model Scan”.

Subsequently, we chose the upper scan of soft tissue in “PLY” format and aligned them using again AI assistant, accessing the planning data.

In the new planning data, we were able to obtain the desired overlap to start analyzing the files and the respective measurements. We collected these data and compared them with previous studies on the subject, which were also based on the processing of digital datasets and digital data collections.

CBCT model was chosen as the reference in the various mediations, being able to analyze the distances between the bone and mucosal surfaces, focusing on the thickness of the palatal soft tissue, at a quantitative level.

Then, these overlaid data were properly imported into the investigation Geomagic® software (44) and into the CoDiagnostiX® software (43), to be analyzed.

The entire palatal area was chosen as the overall region of interest (Fig. 1), starting from the anterior up to the posterior area with a limit in the position the second molar, using a distance of 3 mm and 8mm from the dental palatal gingival margin and a segmentation of the palatal area, in order to compare and contrast the measurements at 3D level between the reference values of the previous studies and those obtained from the analysis.

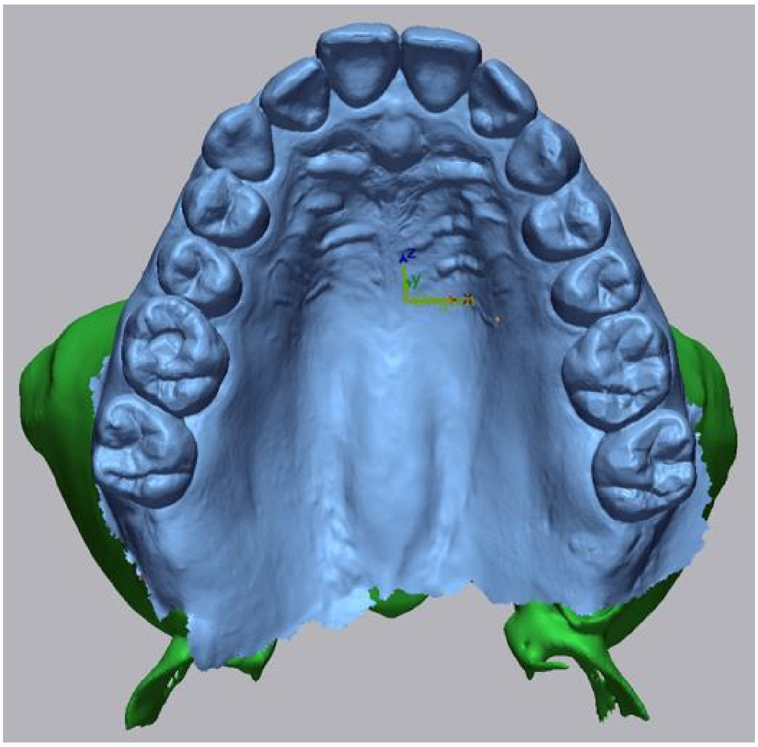


Fig. 1 Representing the overall region of interest (ROI)

The surface discrepancy between the bone model and the gingival relief model will be calculated. To visualize the local volumetric differences, the discrepancies will be displayed on the rendered volume as color-coded distance maps.
The descriptive characteristics of ROIs (Region of Interest) 1-4 will be expressed in millimeters (mm) and evaluated by mean distance (MeanDist), minimum distance (MinDist) and maximum distance (MaxDist). These values represent an average of the thicknesses of interest. The total

sum of these values will be accompanied by the standard deviation (SD ±), providing a measure of the variability of the data.

3.4 Specific and subdivided areas that were analyzed in STL models

ROI-1	palatal area from the canine to the first premolar (PA_CPM1)
ROI-2	palatal area from the first premolar to the second premolar (PA_PM1PM2)
ROI-3	palatal area from the second premolar to the first molar (PA_PM2M1)
ROI-4	palatal area from the first molar to the second molar (PA_M1M2)

The volumetric discrepancies obtained from the analysis of the digital artefacts displayed in the Geomagic® software (44), regarding the rendered volume, will be encoded in the form of a color-coded distance map, which according to color coding ranges represent the distribution of palatal soft tissue volumes.

To select areas for analysis in both palatal dental hemiarch's, we adopted a method involving the arrangement of a horizontal line consisting of five points placed in the gingival margins of five specific teeth (canine, first premolar, second premolar, first molar and second molar).
After accurately positioning the 3D model of the jaw in space within the Geomagic® software (44), the process of drawing reference lines began. Initially, the 'curves' option was selected and then a section called 'spines' was opened. Through this section, it was possible to position the reference points along the gingival margin of the teeth within the designated study area. These points will serve as a reference for identifying the areas to be examined (Fig. 2).

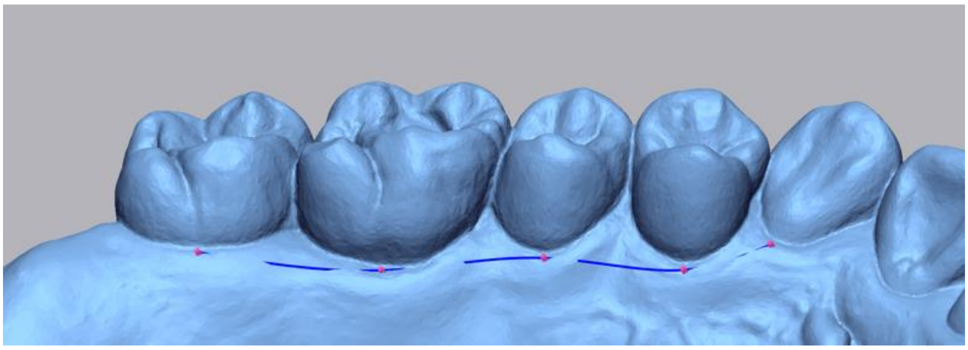


Fig. 2 Representing the horizontal line and the five points of reference.

The line will subsequently be shifted in the palatine direction, in increments of 3 mm and 8 mm respectively, generating a set of measurement points (Fig. 3 and Fig. 4).

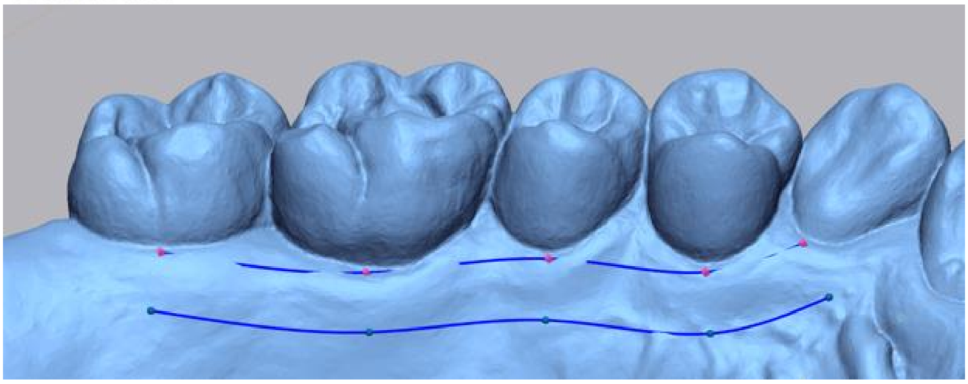


Fig. 3 Representing the dislocation of 3 mm of the horizontal line.

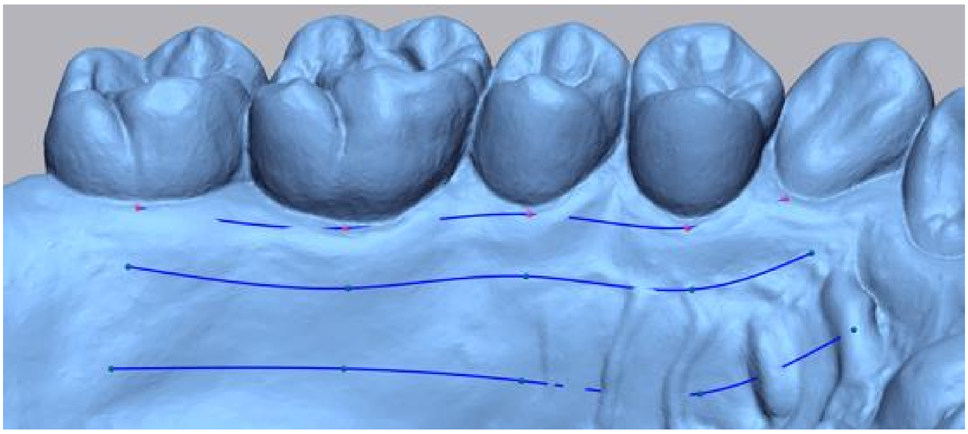
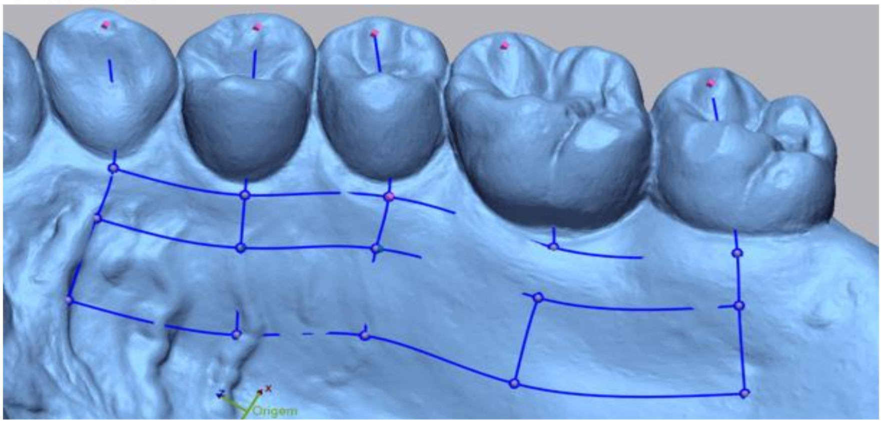


Fig. 4 Representing the dislocation of 3 and 8 mm of the horizontal line.

The specific area of analysis will be defined by joining the 15 points resulting from the line dislocations (Fig. 5 (A)and 5(B)). This process will allow the exact areas under study to be precisely determined (27).

Additionally, five vertical lines will be drawn perpendicular to the gingival margin, positioned between the canine and maxillary second molar. These lines will be used to demarcate the specific areas formed by the union of the previously displaced measurement points and lines.



(A)

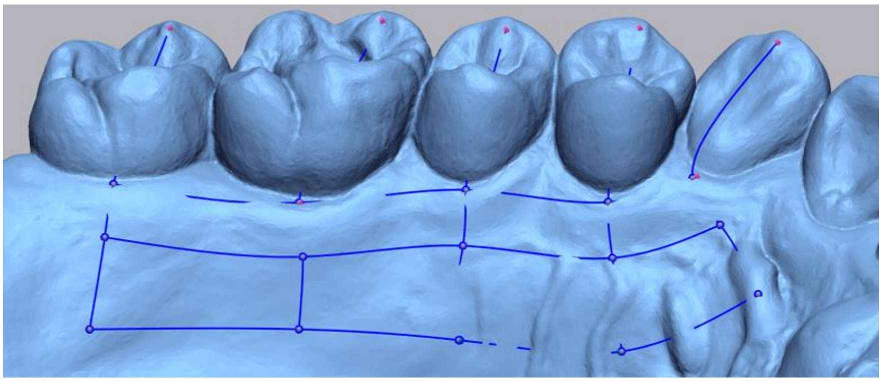
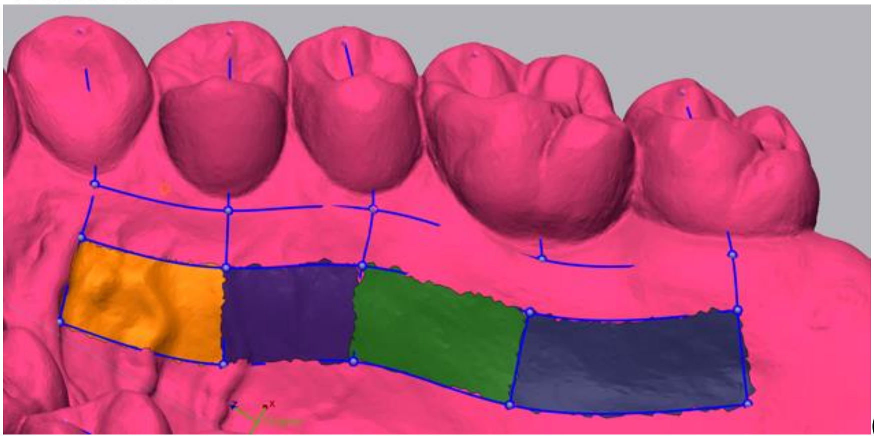

(B)

Fig. 5 Representing in both hemiarch the intersection between the horizontal lines and the 5 vertical lines (A) (B).

The overall region of interest (ROI) was subdivided into 4 different sections, defined in advance to facilitate conclusions on the different palatal sections (Fig. 6(A) and 6(B)).

The areas subject to analysis will be those between 3 mm and 8 mm away from the gingival margin (Fig. 6(A) and 6(B)). This interval was chosen based on its clinical relevance and the need to understand the characteristics of the gingival tissues in this range of distances. This methodological approach ensures accurate assessment of gingival conditions in a scientifically and reproducible manner.


(A)

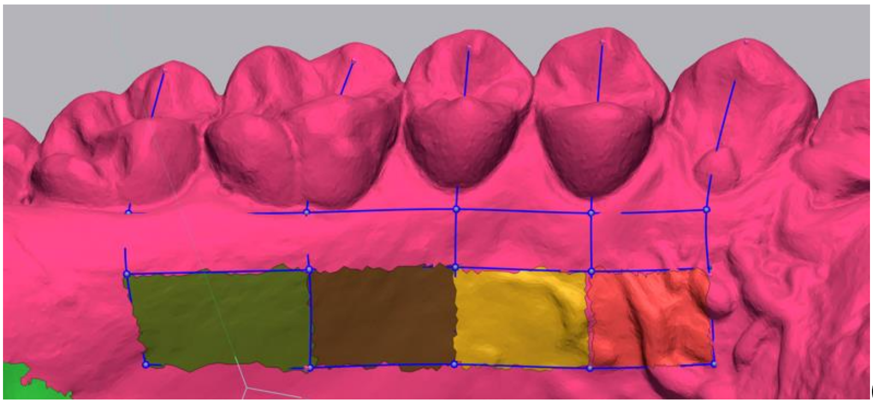

(B)

Fig. 6 Representing in both hemiarch the specific area that was analyzed (A) (B).

3.5 Specific parameters and variables regarding CBCT images

Measurement of the palatal angle and reference points on the image of the second molar level (Pang)
Measurement of the distance between the second molars, at the level of the cement enamel line (D_2MJEC)
Measurement of the palatal depth according to the distance between the center of the mid palatal suture and the line of the distance between the second molars (PD)
Measurement of the apex-coronal distance from the path of the GPA to the CEJ of the second molar (GPF_PACM)

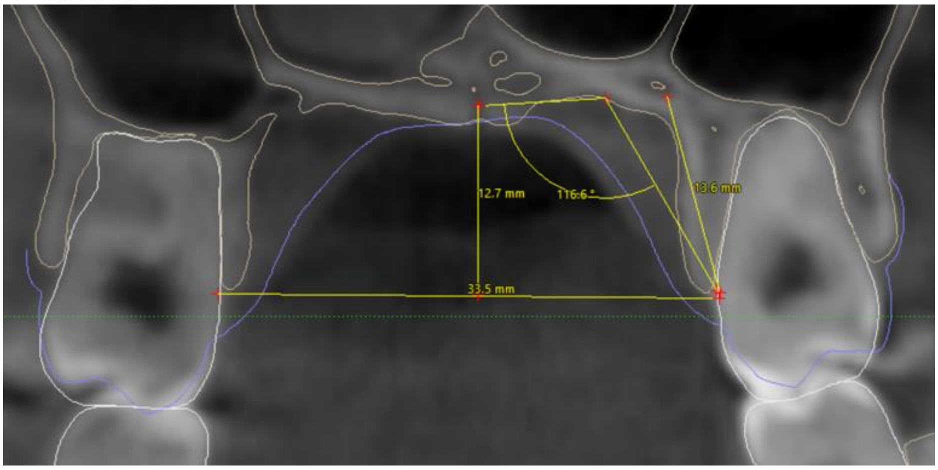


Fig. 7 This image represents the points and the lines regarding the measurement of the PA, the PD, and the D_2MJEC (coronal view).

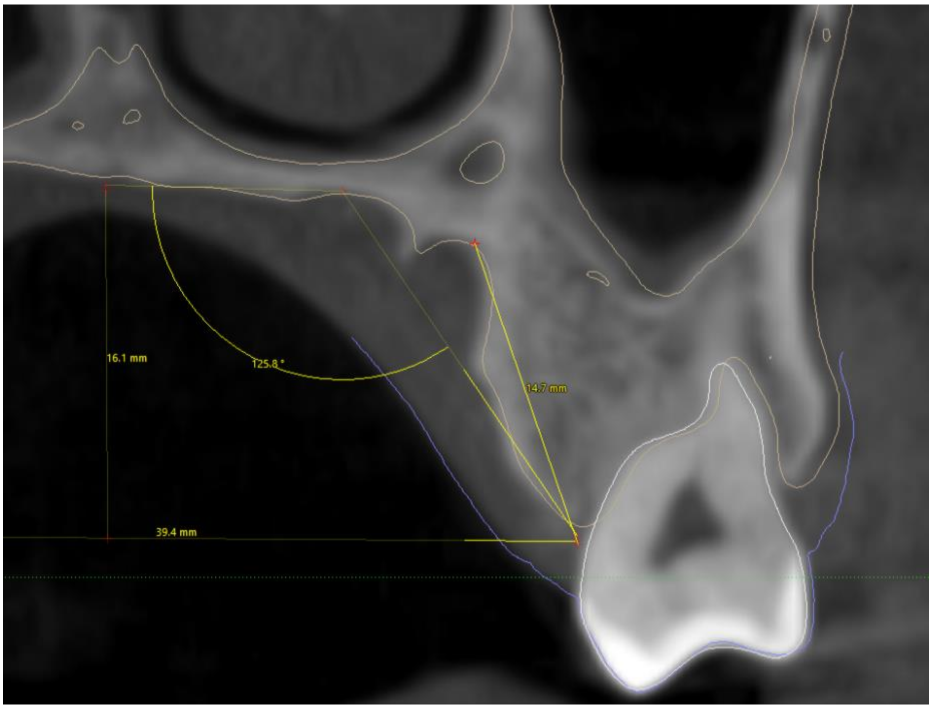


Fig. 8 This image represents the points and the lines regarding the measurement of the GPF_PACM (coronal view).

Using the CoDiagnostiX® software(43), measurements on DICOM files obtained from the CBCT were taken according to the required parameters.

The palatal depth and palatal angle will be taken at the level of the second molar. Three reference points will be determined for measuring the PA (palatal angle): (1) CEJ, (2) the most apical point of the alveolar ridge and (3) the midpalate suture. The angle formed between these three points was recorded as PA. For the measurement of PD, a line passing through the CEJ of the second molars and perpendicular to the base plane was drawn on the image, and a straight line was formed from the midpalate suture to form a right angle with this line (24).

3.6 Specific parameters and variables regarding palatal artery

Measurement of the distance between the position of the GPF in relation to the teeth (GPF_PRT)
Measurement of the distance between the GPF and the median suture (D GPF_MS)
Measurement of the distance between the GPF and the inter incisional foramen (D GPF_IIF)

Using the coDiagnostiX® software (43), based on the position of the GPF visible in the CBCT, measurements were conducted starting from its position and connecting the position of all teeth, where present, starting from the second molar up to the central incisor at the level of the JEC (cementoenamel junction) line (Fig.10). In the same area of analysis always starting from the position of the GPF, the distance between it, the median suture and inter incisional foramen was calculated by combining these structures (Fig.9).

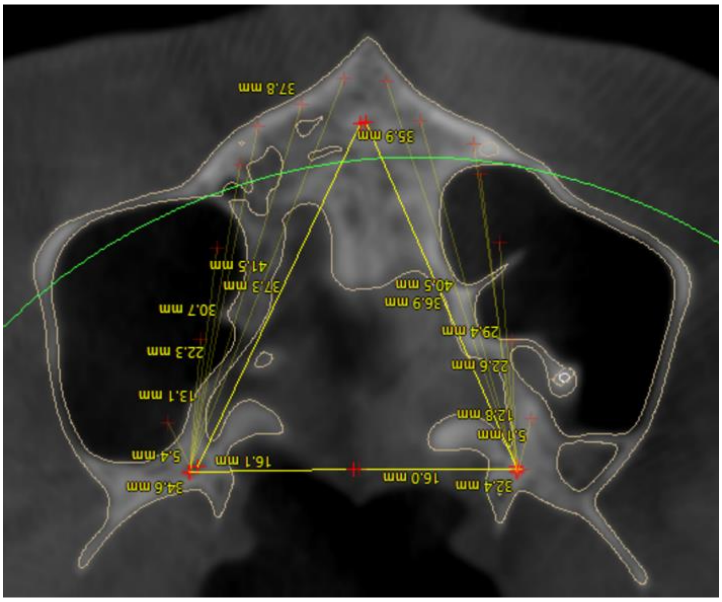


Fig. 9 Representing the distance between the GPF and the median suture, and the distance between the GPF and the inter incisional foramen (axial view).

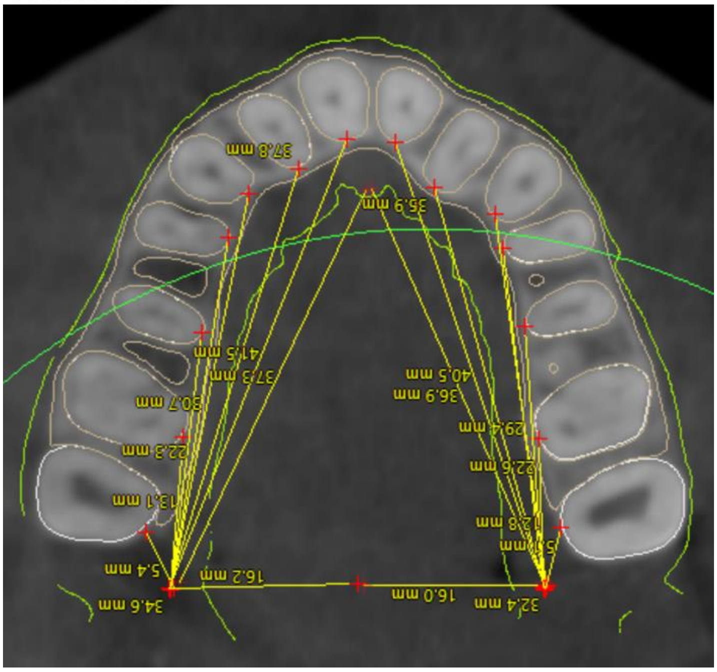


Fig. 10 Representing the distance between the position of the GPF in relation to the teeth (axial view).

According to these, with the use of three-dimensional images obtained from CBCT we measured the changes in patients in the position of the GPF in relation to the incisal foramen, to the midpalate suture and JEC of the teeth comparing them with previous studies.

3.7 Data analysis procedures

In this study, after collecting the data, it was coded and entered a database in the Statistical Package for the Social Sciences (SPSS) software version 26.0, where the statistical treatment was carried out. The processing was carried out considering the objectives of the study. The descriptive analysis used statistical measures: mean, standard deviation and median, as well as graphical representations.

The inferential analysis used parametric and non-parametric tests: t and Mann-Whitney to compare means between two independent groups. Spearman's correlation coefficient was used, since the assumption of normality was not met, to measure the linear relationship between different variables.

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4. Results

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4. Results

Data was collected from 49 patients, 51.0% (n=25) of whom were female. The average age of the women was 31.52 years with a standard deviation of 12.45 years and the average age of the men was 33.00 years with a standard deviation of 15.35.

The distances between the bone and gingival surfaces over the entire palatal region of interest (ROI 1-4), were examined for all 49 test subjects. Also, the different variables and parameters regarding the palatal artery, the palatal angle, and the palatal depth.

Table 1 Summary of demographic information and variables examined in patients

CATEGORY	**SUBCATEGORY**	**VALUE**
Patients	Total number	49
Sex distribution	Female	25 (51.0%)
	Male	24 (49,0%)
AVERAGE AGE		**VALUE/YEARS**
WOMEN	Average age of women/ Standard deviation (women)	31.52 ± 12.45
MEN	Average age of men/ Standard deviation (men)	33,00 ± 15.35
PALATAL REGION OF INTEREST (ROI 1-4)	Number of subjects examined	49
OTHER VARIABELS AND PARAMETERS	Palatal artery	Examined
	Palatal Angle	Examined
	Palatal Depth	Examined

This table summarizes in an organized manner key information regarding patient demographics, average ages and the specific areas examined in the study.

4.1 Geomagic analysis

4.1.1 The palatal masticatory mucosa

The distances measured in the individual palate sections (ROI 1-4), divided from anterior to posterior, are shown in Table 2.

About the palatal area "**ROI-1**", the thickness averages in 1st quadrant, the Meandist was 2.92 ± 0.62 mm, while the MinDist averaged 2.96 ± 1.14 mm and the MaxDist 4.45 ± 0.53 mm. In 2nd quadrant, the thickness averages were 2.97 ± 0.52 mm, 3.28 ± 1.24 mm, and 4.57 ± 0.42 mm, respectively.

For the palatal area "**ROI-2**", the thickness averages in 1st quadrant were 3.10 ± 0.59 mm for the Meandist, 2.35 ± 0.79 mm for the MinDist and 4.18 ± 0.61 mm for the Maxdist. In 2nd quadrant, the thickness averages were 3.08 ± 0.66 mm, 2.72 ± 1.16 mm, and 4.39 ± 0.58 mm.

For the palatal area "**ROI-3**", 1st quadrant, the thickness averages were 2.72 ± 0.71 mm for the Meandist, 1.92 ± 0.79 mm for the MinDist and 4.13 ± 0.66 mm for the Maxdist. In 2nd quadrant, the thickness averages were 2.63 ± 0.63 mm, 1.76 ± 0.74 mm, and 4.28 ± 0.62 mm.

For the palatal area "**ROI-4**", in 1st quadrant, the thickness averages were 2.43 ± 0.76 mm for the Meandist, 1.64 ± 0.73 mm for the MinDist and 4.02 ± 0.80 mm for the "Maxdist". In 2nd quadrant, the thickness averages were 2.34 ± 0.70 mm, 1.70 ± 1.03 mm, and 4.21 ± 0.65 mm.

In the palatal area "**ROI-4**", in 1st quadrant, the thickness average was 2.43 ± 0.76 mm, with 50% of the observations within the 2.00 mm mean; the Mindist was 1.64 ± 0.73 mm, with 50% of the observations below 1.66 mm, while the Maxdist was 4.02 ± 0.80 mm, with 50% of the observations within 4.33 mm.

In 2nd quadrant, the Meandist was 2.34 ± 0.70 mm, with 50% of the observations within 2.28 mm; the Mindist was 1.70 ± 1.03 mm, with 50% of the observations below 1.48 mm, while the Maxdist was 4.21 ± 0.65 mm, with 50% of the observations within 4.38 mm.

Overall, the results show low scatter in both quadrants, with standard deviation values of less than one, except for the Mindist between the ROI-1 in both quadrants and between the ROI-4 in 2nd quadrant. Similar behavior is observed between the quadrants, with higher results in the Maxdist and lower results in the Mindist.

Table 2 Palatal Thickness Measurements in (ROI 1-4) from STL Models: Parameters and Statistical Analysis

STL models		**Parameters used**					
Palatal thickness	**Quadrant**	**Mean**		**Minimum**		**Maximum**	
		$\bar{X}$**±s**	$\tilde{X}$	$\bar{X}$**±s**	$\tilde{X}$	$\bar{X}$**±s**	$\tilde{X}$
ROI-1	**1st**	2,92±0,62	2,88	2,96±1,14	2,65	4,45±0,53	4,58
	2nd	2,97±0,52	2,82	3,28±1,24	3,16	4,57±0,42	4,65
ROI-2	**1st**	3,10±0,59	3,10	2,35±0,79	2,27	4,18±0,61	4,27
	2nd	3,08±0,66	3,09	2,72±1,16	2,36	4,39±0,58	4,51
ROI-3	**1st**	2,72±0,71	2,86	1,92±0,79	1,93	4,13±0,66	4,23
	2nd	2,63±0,63	2,61	1,76±0,74	1,72	4,28±0,62	4,42
ROI-4	**1st**	2,43±0,76	2,00	1,64±0,73	1,66	4,02±0,80	4,33
	2nd	2,34±0,70	2,28	1,70±1,03	1,48	4,21±0,65	4,38

$\bar{X} \pm s - mean \pm standard\ deviation;\ \tilde{X} - median$

Figure 11 presents the diagrams of the extremes and quartiles of the measurements of the different thickness in the two quadrants for four parameters.

ROI-1: 1st quadrant: high concentration in the maximum values, symmetry in the mean values, greater dispersion in the minimum values.

2nd quadrant: concentration in the maximum values, greater dispersion in the minimum values, high concentration of mean values between the 1st quartile and the median.

ROI-2: 1st quadrant: relative symmetry in all parameters, with the maximum most dispersed.

2nd quadrant: symmetry in the mean values, minimum dispersion, concentration in the maximum values.

ROI-3: Identical behavior in both quadrants: symmetry in the mean values, minimum concentration in the lowest results, maximum concentration in the highest values.

ROI-4: 1st quadrant: high concentration of mean values between the 1st quartile and the median, dispersion in the lowest and highest values.

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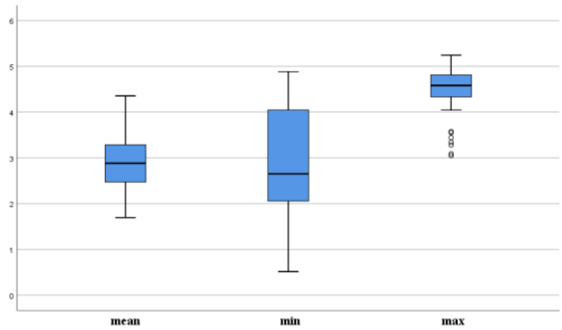
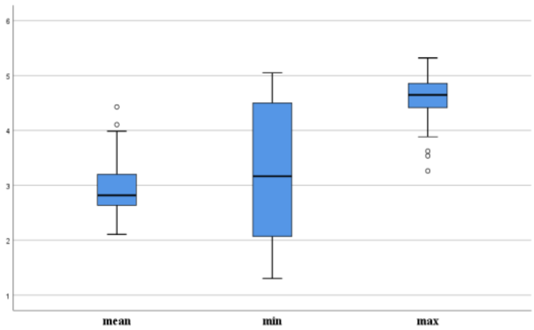
2nd quadrant: symmetry in the parameters and greater definition of the results.

In general, the observed dispersion reflects the distribution of results between the minimum and maximum and between the 1st and 3rd quartile for each case.

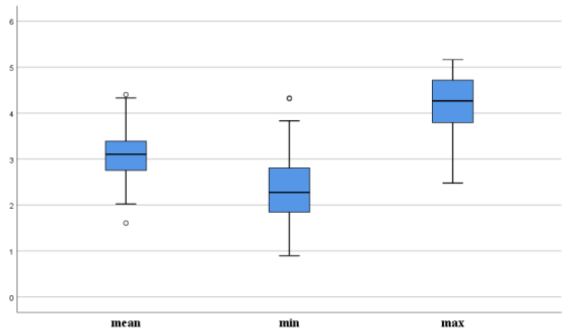
1st Quadrant	2nd Quadrant

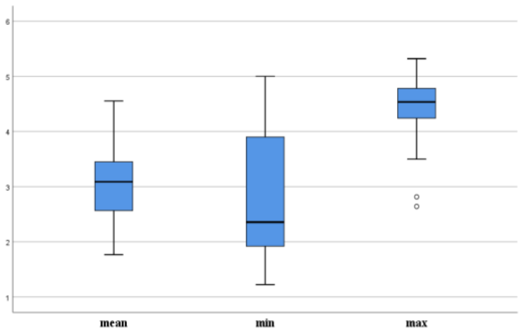
ROI-1



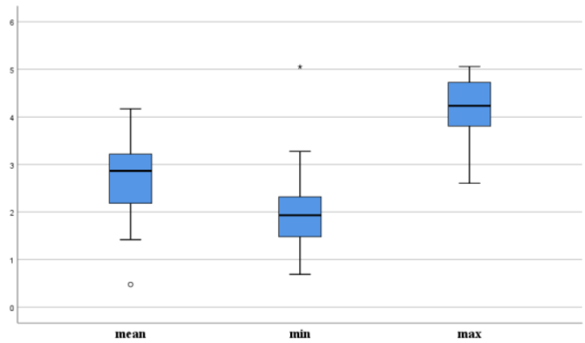


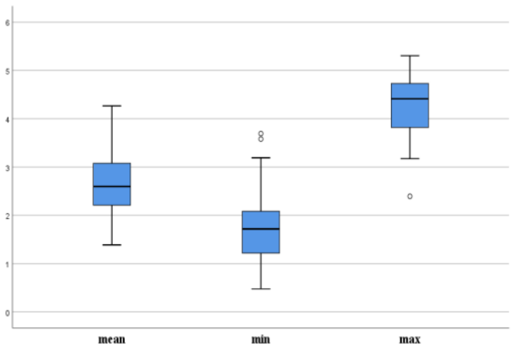
ROI-2





ROI-3





ROI-4

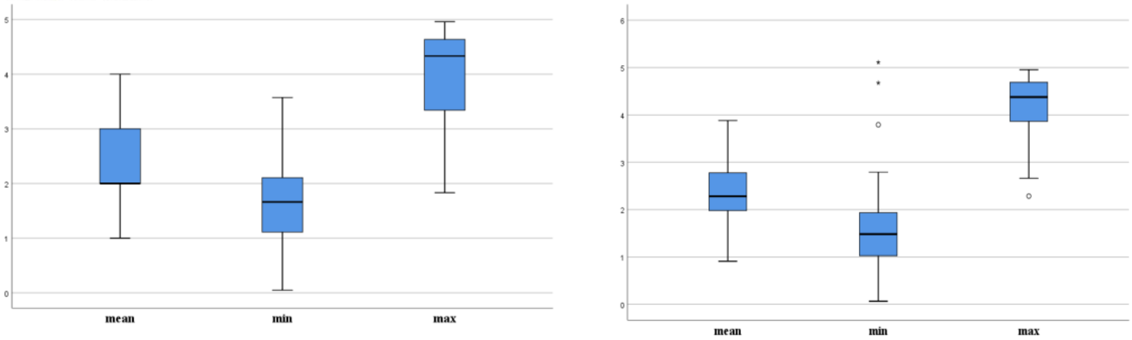


Fig. 11 Diagrams of extremes and quartiles

4.1.2 The palatal masticatory mucosa measurements in relation to sex

Table 3 shows the results of the measurements in the two quadrants and in three parameters in relation to sex.

In almost all situations, male participants recorded higher average values. This was not the case for "ROI-3" in the 1st quadrant and minimum parameter and the 2nd quadrant in the mean and minimum parameters. The Mann-Whitney non-parametric test showed that in the "ROI-1" measurement in the 2nd quadrant, for the minimum parameter, the differences observed were statistically significant, i.e. the results for men were significantly higher.

For the maximum parameter in both quadrants in the "ROI-1" measurement and in the 2nd quadrant in all the other measurements, it was also concluded that the differences observed were statistically significant, i.e. the results obtained by men were significantly higher than those obtained by women.

Table 3 Sex characterization of the measurement areas.

STL models			**Parameters used**					
Palatal area	**Quadrant**	**Sex**	**Mean Thickness**		**Minimum Thickness**		**Maximum Thickness**	
			$\bar{X}$**±s**	**T (p)**	$\bar{X}$**±s**	**T (p)**	$\bar{X}$**±s**	**T (p)**
ROI-1	**1st**	**Female**	2,77±0,43	-1,760	2,76±1,15	- 1,546*	4,28±0,59	-2,516*
		Male	3,08±0,74	(0,087)	3,16±1,13	(0,122)	4,62±0,42	(**0,012**)
	2nd	**Female**	2,92±0,53	-0,703	2,65±0,99	-3,451*	4,40±0,43	-4,035
		Male	3,03±0,51	(0,482)	3,94±1,14	**(0,001)**	4,74±0,33	**(0,005)**
ROI-2	**1st**	**Female**	2,96±0,56	-1,782*	2,15±0,62	-1,813	4,09±0,59	-1,029
		Male	3,24±0,59	(0,075)	2,56±0,90	(0,077)	4,27±0,62	(0,309)
	2nd	**Female**	3,00±0,63	-0,704	2,53±1,12	-0 933	4,14±0,68	-2,685
		Male	3,15±0,69	(0,486)	2,88±1,20	(0,357)	4,60±0,39	(**0,017**)
ROI-3	**1st**	**Female**	2,65±0,78	-0,658	1,93±0,92	-0,429*	4,04±0,71	-0,995
		Male	2,79±0,64	(0,514)	1,91±0,66	(0,668)	4,23±0,59	(0,325)
	2nd	**Female**	2,65±0,59	0,254	1,76±0,66	-0,219*	4,00±0,62	-3,408
		Male	2,60±0,68	(0,800)	1,76±0,83	(0,827)	4,57±0,49	(**0,001)**
ROI-4	**1st**	**Female**	2,26±0,70	-1,446*	1,54±0,69	-1,012	3,93±0,74	-1,365*
		Male	2,63±0,79	(0,148)	1,76±0,76	(0,317)	4,12±0,87	(0,172)
	2nd	**Female**	2,29±0,67	-0,520	1,46±0,60	-1,484	4,07±0,57	-2,051*
		Male	2,40±0,74	(0,606)	1,94±1,31	(0,146)	4,35±0,71	(**0,040**)

$\bar{X}$±s – mean ± standard deviation; T (p) - T-test statistic (significance level); *- application of the Mann-Whitney non-parametric test, the normality assumption was not met

Table 4 shows the Spearman correlation coefficients (since the assumption of normality for all distributions was not checked) between age and the parameters (mean, minimum and maximum) of each measurement in each quadrant. Age shows a statistically significant correlation with all the measurements in the mean parameter in both quadrants, except for the 2nd quadrant in the measurement "ROI-1". The correlation is direct, i.e. with increasing age there is an increase in the thickness parameter in the measurements under study, but the intensity of the correlation is weak. There was also a statistically significant, direct, and weak correlation between age: and the measurement "ROI-2" in the 1st quadrant in the minimum parameter (r=0.462) and the measurement "ROI-3" in the 1st quadrant in the minimum parameter (r=0.374).

Table 4 Spearman's correlation between age and the parameters of the measurements studied.

STL models		**Parameters used**		
Palatal area	**Quadrant**	**Mean Thickness**	**Minimum Thickness**	**Maximum Thickness**
		***r* (p)**	***r* (p)**	***r* (p)**
ROI-1	**1st**	**0,384** (0,007)	-0,062 (0,678)	-0,085 (0,564)
	2nd	0,242 (0,109)	-0,039 (0,800)	-0,079 (0,604)
ROI-2	**1st**	**0,389** (0,008)	**0,462** (0,001)	0,083 (0,588)
	2nd	**0,371** (0,046)	0,202 (0,217)	0,079 (0,629)
ROI-3	**1st**	**0,473** (0,001)	**0,374** (0,011)	0,277 (0,062)
	2nd	**0,428** (0,004)	0,243 (0,116)	0,057 (0,713)
ROI-4	**1st**	**0,457** (0,002)	0,286 (0,057)	0,264 (0,080)
	2nd	**0,323** (0,045)	0,046 (0,782)	-0,048 (0,771)

r - correlation coefficient; p - significance level

4.2 CodiagnostiX analysis

Table 5 shows the results obtained for the specific parameters and variables of the CBCT images. The mean palatal angle (Pang) was 112.12 ± 9.51º, an identical result for women and men, so the small differences between them were not statistically significant. The overall mean palatal depth was 14.35 ± 2.25mm, 13.58 ± 1.62 for females and 15.26 ± 2.57mm for males. The differences between men and women for this parameter were statistically significant (T=-2.692; p<0.05). The average position of the FPF in relation to the tooth was 38.15 ± 6.85mm. The results obtained by women and men were identical and close to the overall value, and the small differences between men and women were not statistically significant.

The correlation coefficients between age and the specific parameters and variables of the CBCT images were determined. The coefficient between age and the palatal depth parameter is statistically significant, is in the direct direction and its intensity is weak.

Table 5 Characterization of specific CBCT image parameters, results by sex and correlation with age

Specific parameters and variables regarding CBCT images	Total	Sex		T (p)	Age
		Female	Male		
	$\bar{X}$±s	$\bar{X}$±s	$\bar{X}$±s		r (p)
Pang (º)	112,12±9,51	112,17±6,54	112,09±12,33	0,027 (0,978)	-0,011 (0,941)
PD (mm)	14,35±2,25	13,58±1,62	15,26±2,57	-2,692 (0,010)	**0,393** (0,007)
Position of GPF in relation to the teeth (mm)	38,15±6,85	39,36±3,28	36,82±9,28	-0,339* (0,748)	0,129 (0,427)

$\bar{X}$±s – mean ± standard deviation; T (p) - T-test statistic (significance level); *- application of the Mann-Whitney non-parametric test, the normality assumption was not met; r - correlation coefficient; p- significance level

Table 6 Spearman's correlation between palate angle and parameters of the measurements

STL models		Parameters used		
Palatal area	**Quadrant**	**Mean**	**Minimum**	**Maximum**
		***r* (p)**	***r* (p)**	***r* (p)**
ROI-1	**1st**	-0,010 (0,946)	-0,117 (0,446)	0,111 (0,467)
	2nd	-0,165 (0,295)	-0,147 (0,352)	-0,134 (0,397)
ROI-2	**1st**	-0,078 (0,622)	-0,025 (0,875)	0,032 (0,843)
	2nd	-0,058 (0,727)	0,103 (0,544)	-0,122 (0,467)
ROI-3	**1st**	-0,018 (0,909)	0,044 (0,781)	0,140 (0,371)
	2nd	-0,059 (0,712)	0,111 (0,496)	-0,182 (0,255)
ROI-4	**1st**	0,008 (0,961)	0,052 (0,743)	0,119 (0,452)
	2nd	-0,004 (0,983)	0,127 (0,459)	-0,145 (0,398)

r - correlation coefficient; p - significance level

Table 6 shows the Spearman correlation coefficients between the palate angle and the parameters of the measurements studied.

It was concluded that the palate angle has no statistically significant linear correlation with the measurements, in the different parameters: mean, minimum and maximum and in both quadrants.

4.3 Artery measurement

Table 7 Characterization of the specific variables of the palatal artery, results by sex and correlation with age.

Palatine artery variables	Quadrant	Sex	Results			Age
			$\bar{X}$±s	T (p)	Global $\bar{X}$±s	r (p)
Central incisor	**1st**	**Female**	47,34±3,73	-0,970	47,88±3,97	0,088
		Male	48,44±4,21	(0,337)		(0,547)
	2nd	**Female**	47,25±3,73	-1,170	47,88±3,86	0,088
		Male	48,54±3,96	(0,248)		(0,547)
Lateral incisor	**1st**	**Female**	44,49±3,80	-1,000	45,07±4,03	0,082
		Male	45,65±4,24	(0,322)		(0,581)
	2nd	**Female**	44,83±3,54	-0,521	45,11±3,74	0,151
		Male	45,39±3,99	(0,605)		(0,307)
Canine	**1st**	**Female**	39,92±3,66	-1,066	40,50±3,65	-0,013
		Male	41,05±3,63	(0,292)		(0,930)
	2nd	**Female**	40,00±3,14	-0,627	40,29±3,25	0,103
		Male	40,60±3,40	(0,534)		(0,486)
1st Premolar	**1st**	**Female**	34,32±2,97	-1,884	35,21±3,31	-0,056
		Male	36,10±3,45	(0,066)		(0,714)
	2nd	**Female**	34,92±3,21	-0,895	35,32±3,10	0,045
		Male	35,75±3,00	(0,381)		(0,772)
2nd Premolar	**1st**	**Female**	28,22±3,32	-1,895	29,17±3,54	-0,097
		Male	30,17±3,57	(0,065)		(0,528)
	2nd	**Female**	41,55±61,34	0,977	35,67±43,32	0,106
		Male	29,79±3,29	(0,386)		(0,506)
1st molar	**1st**	**Female**	19,80±3,10	-1,408	20,47±3,27	0,080
		Male	21,16±3,37	(0,166)		(0,600)
	2nd	**Female**	19,97±3,16	-1,135	30,47±3,16	0,014
		Male	21,04±3,13	(0,263)		(0,926)

2nd molar	**1st**	**Female**	12,56±3,02	-1,081	13,06±3,03	0,243
		Male	13,54±3,03	(0,262)		(0,108)
	2nd	**Female**	13,10±3,01	-0,325	13,24±2,83	0,104
		Male	13,37±2,69	(0,7469)		(0,493)

$\bar{X}\pm s$ – mean ± standard deviation; T (p) - T-test statistic (significance level); r - correlation coefficient; p-significance level

Table 7 shows the results of the distance between JEC of the teeth and localization of the GPF. Among the different teeth, the mean distances between the GPF and specific landmarks (JCE of the teeth) were relatively similar between quadrants and sexes. For example, in the first quadrant, the average distances for the central incisor, lateral incisor and canine were 47.88±3.97 mm, 45.07±4.03 mm and 40.50±3.65 mm, respectively, with similar results in the second quadrant.

It was concluded that none of the palatine artery variables showed statistically significant differences between women and men. The correlation coefficients of age with the specific parameters and variables of the images of the palatine artery were determined. It was concluded that the patient's age has no statistically significant linear correlation with the measurements.

Table 8 shows the mean distance between the GPF and the cement-enamel junction (CEJ) of the molars was 15.37±1.35 mm, with no statistically significant differences between sexes. The distance between the GPF and the inter incisor foramen had an overall mean of 49.63±52.48 mm, with slight variations between females (41.48±2.23 mm) and males (58.13±74.80 mm), but these differences were not statistically significant. Similarly, the mean distance between the GPF and the median suture was 15.15±1.83 mm, with no significant differences between the sexes.

Table 8 Characterization of the specific parameters of the GPF position, results by sex and correlation with age.

Position of GPF	Total	Sex		T (p)	Age
		Female	Male		
	$\bar{X}$±s	$\bar{X}$±s	$\bar{X}$±s		r (p)
in relation to the apex-coronal distance from the of GPF to CEJ of the molars.	15,37±1,35	15,31±6,54	15,24±1,61	0,190 (0,851)	0,007 (0,960)
Distance between the GPF and the inter incisional foramen	49,63±52,48	41,48±2,23	58,13±74,80	-1,112 (0,272)	-0,116 (0,429)
Between the GPF and the median suture	15,15±1,83	15,07±1,09	15,23±1,29	-0,449 (0,656)	-0,24 (0,871)

$\bar{X}$±s – mean ± standard deviation; T (p) - T-test statistic (significance level); *- application of the Mann-Whitney non-parametric test, the normality assumption was not met; r - correlation coefficient; p- significance level

The correlation coefficients between age and the specific parameters and variables of the GPF position were determined. It was concluded that the patient's age has no statistically significant linear correlation with the measurements analyzed.

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5. Discussion

5. Discussion

Although the advantages of preoperative planning are obvious, less attention has been paid to the use of 3D planning for soft tissue applications in planning periodontal treatments, the aim of the present study (12).

When planning a mucogingival surgical procedure for a soft-tissue graft, it is crucial to consider the amount of tissue required and to identify the optimal donor site (22).
Periodontal plastic surgery and implant surgery represent operations of considerable complexity and technical sensitivity, requiring a high level of expertise and specialization on the part of the surgeon (12) During the pre-operative phase, it is essential to consider several critical factors to ensure an optimal outcome in terms of both aesthetics and function. This process includes a thorough assessment of the patient's anatomical condition, detailed planning of the surgical procedure, and the adoption of advanced, customized techniques that consider the specific clinical needs of the case (21). Only through meticulous preparation and careful management of preoperative details can results be achieved that meet the high standards required in terms of dental aesthetics and implant function (19).

Graft thickness is essential in determining the most appropriate treatment and predicting an accurate prognosis. A detailed evaluation of these parameters optimizes the choice of surgery and better predicts post-operative success, allowing customized strategies for optimal functional and aesthetic results (46). Soft tissue grafts are mainly harvested from the palatal masticatory mucosa in periodontal plastic procedures and. their success is closely related to the size and thickness of the graft itself (47).
Since bone sounding is usually performed intraoperatively under anesthesia, preoperative planning based on tissue thickness is impractical and the data collected are limited because they are based on a small number of point measurements, possibly altered by anatomical conformations (38).

The direct method, or bone scanning, is an invasive technique performed under local anesthesia that can be uncomfortable for the patient and measurements can be affected by inflammation and the volume of anesthetic, altering the accuracy of readings, making careful monitoring necessary to obtain reliable results (47).

Subsequent studies have highlighted the need to develop indirect techniques for the evaluation of gingival tissue, including the use of radiological imaging and intraoral scanners, as well as three-dimensional (3D) image collection. These methodologies can be implemented preoperatively and during routine consultations, offering accurate and non-invasive tissue assessment, thus improving the planning and execution of surgical procedures (5,46).

5.1 Palatal area measurements

Measurements of the distances between the bone and gingival surfaces in the palatal region were performed with a combination and superimposition of scanned 3D model of the maxilla and CBCT of the same, analyzing regions of interest (ROI1-4). The measurements were further separated for the two quadrants of the palate (1^{st} and 2^{nd}).

The results show a low dispersion of measurements in both quadrants, with standard deviations of less than one in most cases. Compared to some investigation in the literature, using direct measurement methods with probes or techniques requiring the use of anesthesia, our results appear more reliable and accurate(12,27,48). This is due to the reduced variation between the values obtained, avoiding the limitations of linear point measurements, which can be influenced by the irregular structure of the alveolar bone or a non-perpendicular position(12).

However, greater variability is noted in the minimum areas of the palate between the ROI-1 in both quadrants and between the ROI-4 in the 2^{nd} quadrant. Similar behavior was observed between the two quadrants, with greater results for the maximum thickness and less for the minimum thickness.

These results suggest a consistent uniformity in palatal measurements, providing a reliable basis for further studies and clinical applications. The minimal differences between the quadrants indicate that individual variations can be effectively managed through detailed preoperative planning and the use of advanced measurement technologies such as the intraoral scanner, consequently, as confirmed by the most recent literature, can be seen as a promising methodology, as it allows the use of digital software to measure thickness at different points and volumes, accurately identifying the areas to be analyzed (21,47).

5.1.1 Minimum parameter "ROI-1" in 2nd quadrant

Statistical analyses, in particular the non-parametric Mann-Whitney test, revealed statistically significant differences in the values of the minimum parameter for the "ROI-1" area in 2nd quadrant. In this specific measurement, male subjects recorded significantly higher values than females. According to Ilkim Karadag et al the thinnest mucosa was in the region of the first molar tooth(24), contrary to our study, but according to Oduncuoğlu BF et al this minimum parameter was in the same area(47) so we have a concordance. It is agreed in both studies, that the palatine mucosa was thinner in women than in men (24,47).

In contrast to our study, in research with direct manual measurement, women reflected higher values (27) and not statistically significant difference for sex (5,48).

5.1.2 Maximum Parameter in Different Measurements

Statistically significant differences also emerged when analyzing the maximum parameter between the various measurements of the palatal thickness. In general, male subjects showed higher maximum values than female subjects. This result was consistent in all areas examined, indicating a tendency for males to have a more pronounced maximum size in the palatal regions analyzed.

Furthermore, the analysis of mean palatal mucosal thickness (PMT) scores according to sex revealed that the mucosa was significantly thinner in females than males in all dental regions considered. This observation is in line with the previous reports and existing literature, by the same and different methods, respectively(24,48).

5.2 Sex

The differences observed between the sexes in the measurements of the palatal areas can be attributed to various factors, including structural and functional differences between males and females. Previous studies have shown that craniofacial dimensions and proportions vary greatly between the sexes, significantly affecting palatal area measurements. Such variations are crucial to understanding the differences in palatal tissues between men and women. Therefore, it is observed that both, Oduncuoğlu BF et al and Tonetti MS et al, supports and confirms our findings, demonstrating the importance of considering sex as a significant variable in studies of palatal tissue measurements, especially when supported by advanced imaging methodologies and detailed morphometric analyses, which confirm the relevance of these sex differences(7,47).

The identification of statistically significant differences in the minimum and maximum parameters suggests that palatal measurements could be useful in identifying and better understanding sex-related anatomical variations.

These findings have practical implications in clinical applications, where understanding sex differences in palatal morphology may influence the planning and implementation of orthodontic and surgical treatments.

The study found that male subjects generally had higher mean values in palatal thickness measurements than females, with statistically significant differences observed in specific parameters. These differences highlight the importance of considering sex as a variable in the evaluation of palatal measurements to ensure a more precise and personalised diagnosis and treatment. The present literature confirms these findings, underlining how sex-related anatomical variations should be incorporated into clinical practices to improve the effectiveness of orthodontic and surgical treatment(12,46).

5.3 Correlation Analysis between Age and Palatal Area Measurements

The statistical analysis revealed a direct, albeit weak, and statistically significant correlation between the age of the participants and the mean thickness measurements in both quadrants of the palate.

Specific correlations were identified between age and the minimum parameter in the measurements of area 'ROI-2' and 'ROI-3' in the 1st general quadrant, in agreement with our data, sex and age characteristics were reported as factors that may influence palatal mucosal thickness, but these results must be interpreted with caution because the samples included in this review were not homogeneous across populations, and only a few studies reported specific results for male and female individuals (34).

5.4 CBCT Imaging Parameters

5.4.1 Palatal Angle

Analysis of the CBCT imaging data revealed that the palatal angle had an overall mean of 112.12 ± 9.51º. There were no statistically significant differences between male and female subjects for this parameter, indicating substantial uniformity of palatal angle conformation between the two sexes. This uniformity suggests that the palatal angle represents a relatively stable anatomical measure that is not significantly influenced by sex differences. This is consistent with the existing literature which shows that the values measured in men and women are stable and show no significant variations and that these results underline the relevance of the palatal angle as a reliable parameter for comparative studies and clinical applications, regardless of the sex of the subjects (24). According to Simon Botond et al there is no differences were found in the angles between females and males, in agreement with our study, but the method of measuring PA was totally different from ours (49).

5.4.2 Palatal Depth

Palatal depth showed an overall average of 14.35 ± 2.25 mm. However, a more detailed analysis revealed a significant difference between the sexes.

Statistical comparison between the two groups showed that this difference was statistically significant ($p < 0.05$), indicating that men tend to have a greater palatal depth than women. This difference can be attributed to various factors, according to Alves et al in differences in craniofacial growth and bone structure between the two sexes (50), also according to Pritam Kumar Mankapure et al, agreeing with our study, it is confirmed that the average values of palatal depth were higher in males than in females, however not being statistically significant (51).

5.4.3 Position of the Great Palatal Foramen (GPF) in Relation to the Teeth

Regarding the position of the Great Palatal Foramen (GPF) in relation to the teeth, the overall mean was 38.15 ± 6.85 mm. Statistical analysis revealed no significant differences between the sexes for this parameter, suggesting that the position of the GPF is relatively constant between men and women. This constancy is important for clinical procedures that require a precise location of the GPF, such as palatal anesthesia and some dental surgeries.

The absence of significant differences in palatal angle between sexes suggests that this measurement can be considered sex invariable, facilitating the application of uniform standards in clinical and diagnostic evaluations. In contrast, palatal depth differs significantly between men and women, underlining the importance of taking the patient's sex into account when planning orthodontic treatments and surgeries involving the palate. The invariable position of the GPF between the sexes confirms that techniques based on this measure can be applied uniformly, without the need for sex-specific adjustments(7,24,47).

5.5 Location of the Palatine Artery and Great Palatal Foramen (GPF)

5.5.1 Palatine Artery Variables

The analysis of palatine artery variables revealed no statistically significant differences between male and female subjects. Furthermore, no significant correlation emerged between the participants' age and palatine artery measurements. These results indicate that the position and characteristics of the palatine artery are constant irrespective of the sex and age of the subject, suggesting an anatomical stability of this structure over time and between the sexes, which combines the essential anatomical landmarks for identifying the position of the GPF. Our study contributes to the existing literature by providing the approximate position of the GPF based on its distance from the median suture, inter incisional foramen and distance from the teeth(7,22,34,52).

5.6 Final considerations

The study examined anatomical variations of the palate and their clinical relevance, showing that although there are some correlations between age and palatal area measurements, these are weak and not clinically significant. Sex differences were observed mainly in palatal depth, with men having on average a greater depth than women. Other measures, such as palatal angle and position of the Great Palatal Foramen (GPF), do not show significant differences between the sexes or correlations with age. However, the stability of these measures makes them useful for evaluation and clinical planning regardless of the sex or age of the patient.

Accurate preoperative evaluation, including the combined use of intraoral scanners and cone beam computed tomography (CBCT), is essential to identify the most suitable areas for graft harvesting and reduce the risk of complications. This combination of advanced imaging techniques allows a detailed view of the anatomical structures of the palate, including mucosal thickness and the position of the palatal neurovascular bundle, thus facilitating precise surgical planning and optimal graft harvesting.

These results suggest that anatomical variations of the palate may be influenced by genetic and developmental factors that vary between individuals, but that sex-related differences are limited to specific parameters. The absence of significant correlations with age for palatine artery and GPF position measurements indicates that remain relatively stable over time.

The study provided comprehensive data on maxillary soft tissue and palatine artery position, which are useful for pre-surgical planning, particularly for harvesting graft material. Intra-oral CBCT and 3D scanner techniques proved feasible and informative for these clinical purposes. It also contributes to the understanding of palatal anatomical variations, providing useful data for clinical applications, such as orthodontics and maxillofacial surgery, where detailed knowledge of palatal structures is crucial for treatment planning and execution.

The harvesting of a soft tissue graft from the palatal mucosa may be limited by the thickness of the palatal mucosa and the location of the palatal neurovascular bundle (24). These limitations require a thorough knowledge of the palatal anatomy and careful surgical planning to optimize graft retrieval and minimize complications. It is essential for the surgeon to have a detailed understanding of individual anatomical variations that may influence mucosal thickness in different areas of the palate.

Furthermore, surgical planning must consider specific anatomical guidelines, such as measuring from the gingival margin and avoiding the posterior areas of the palate where the neurovascular bundle is more prominent. This meticulous approach ensures that graft harvesting is performed safely and effectively, maximizing the quantity and quality of tissue harvested and improving post-operative outcomes for the patient.

Using the technique described in detail in this study, it was possible to obtain a three-dimensional visualization of the anatomical characteristics of the soft tissues of the palate for each patient.

Overlapping data comprising both bone structures and soft tissues were integrated and analyzed to exploit the full diagnostic potential offered by complex three-dimensional datasets. This method has significantly improved the ability to assess the patient's condition and plan surgical interventions with greater precision, offering a global view that allows the specific needs of each clinical case to be predicted and addressed. The exceptional accuracy of the measurements allows for precise and detailed data, which is essential for in-depth analysis and accurate monitoring of the soft tissues of the palate (21).

6. Conclusion

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6. Conclusion

This study provides a comprehensive analysis of palatal area measurements, highlighting the accuracy and reliability of using 3D models and CBCT imaging compared to traditional direct measurement methods.

Consistent and low variance measurements were observed in different regions of the palate, suggesting uniformity and reliability. This was especially noted when comparing the first and second quadrants. The study found that male subjects generally had higher mean values in palatal area measurements than females, with statistically significant differences observed in specific parameters.

Statistically significant differences were identified between male and female subjects, with males generally having greater palatal depth and maximum dimensions in the palatal regions. A weak but statistically significant correlation was found between age and some palatal measurements, indicating that age may slightly influence palatal size.

Palatal angle showed no significant differences between the sexes. The position of the GPF remained constant between sexes, ensuring that clinical procedures requiring precise location of the GPF can apply uniform standards.

No significant differences in palatine artery variables were found between sexes or age groups, indicating the anatomical stability of this structure.

These findings highlight the importance of incorporating sexes differences and age correlations into clinical practices to improve the accuracy and personalization of dental treatments.

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8. Attachments

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8. Attachments

8.1 Ethical principles

The result of the investigation, once publicly disclosed, were formulated in such a way as to exclude any element that might allow individual identification of the patients involved. This strategy is designed to scrupulously preserve the confidentiality and privacy of the data collected during the study. At the same time, this approach ensures that research-relevant information is transparent and accessible, thus contributing to the advancement of the scientific community and the promotion of the well-being of society.

Clinical data, which are valuable for the analysis and understanding of results, are kept in a state of absolute confidentiality. Safeguarding the privacy of patients is paramount, and therefore, access to the data is strictly limited to the experts involved in the project. The data collected are exclusively used by the investigation team, maintaining privacy and confidentiality, not being made available to third parties, ensuring that it is used responsibly and in the interest of scientific research.

The Ethics Committee has approved the project with a favorable opinion under the title 'Application of digital technologies in oral rehabilitation' No. 201.

8.2 Normality test

In this study, after collecting the data, it was coded and entered a database in the Statistical Package for the Social Sciences (SPSS) software version 26.0, where the statistical treatment was carried out. The processing was carried out considering the objectives of the study. The descriptive analysis used statistical measures: mean, standard deviation and median, as well as graphical representations.

The inferential analysis used parametric and non-parametric tests: t and Mann-Whitney to compare means between two independent groups. Spearman’s correlation coefficient was used, since the assumption of normality was not met, to measure the linear relationship between different variables.

8.3 Ethics clearance document

Parecer sobre o projeto nº 201
Comissão de Ética para a Saúde da Universidade Católica Portuguesa
Mandato 2019/2023

Projeto de Investigação
Na reunião do dia 24 de março de 2022 a CES-UCP esteve reunida e apreciou do ponto de vista ético os elementos submetidos pelo investigador principal. Após apreciação redige o parecer que agora se apresenta.

Título: APLICAÇÃO DE TECNOLOGIAS DIGITAIS NA REABILITAÇÃO ORAL. Mestrado Integrado em Medicina Dentária. Estudo clínico sem intervenção.
Data prevista de início: 02/05/2022 **Data prevista de conclusão**:31/12/2031

Investigador Principal: André Ricardo Maia Correia, UCP
Equipa de Investigação (CV´s submetidos): Patrícia Fonseca, Professora Auxiliar FMD-UCP; Nélio Veiga, Professor Auxiliar da FMD-UCP; Tiago Marques: Assistente Convidado da FMD-UCP; Filipe Araújo: Assistente Convidado da FMD-UCP; Ana Margarida Silva: Assistente Convidada da FMD-UCP; Cristina Figueiredo: Assistente Convidada da FMD-UCP; Helena Salgado: Assistente Convidada da FMD-UCP; Luís Pereira Azevedo, Investigador do CIIS, Doutorando na Univ.; Complutense de Madrid, e Investigador da Universidade de Genebra.; Bruno Oliveira – Médico Dentista, Docente Convidado da pós-graduação de Reabilitação Oral Protética Digital da FMD-UCP; Sandro Lopes – aluno 5º ano FMD-UCP (2021/2022); Maria Garcia – aluno 5º ano FMD-UCP (2021/2022); Diana SottoMayor – aluno 5º ano FMD-UCP (2021/2022)

Resumo: A reabilitação oral compreende um conjunto de procedimentos com uma sequência temporal bem estabelecida que vai desde o diagnóstico, planeamento, restabelecimento de estruturas duras ou moles perdidas na cavidade oral e follow-up sistematizado de cada caso em particular. A necessidade crescente de um atendimento personalizado e individualizado fez crescer no mercado sistemas digitais (equipamentos e tecnologias) que se enquadram nas diferentes fases de uma reabilitação oral. A opção por um determinado tipo de reabilitação (próteses dentárias fixas ou removíveis; muco-suportadas, dento-suportadas, dento-muco-suportadas ou implanto-suportadas), depende de condicionantes anatómicas, fisiológicas e socioeconómicas do paciente, mas também da aptidão/competências dos profissionais envolvidos em todo o processo de reabilitação oral (particularmente, Médicos Dentistas, Assistentes Dentárias, Higienistas Orais e Técnicos de Prótese Dentária), e do seu acesso aos diferentes equipamentos, tecnologias e biomateriais. Neste projeto pretende-se analisar parâmetros morfo-anatómicos através de técnicas de metrologia não invasivas em pacientes que foram submetidos a algum tipo de reabilitação oral para aferir, determinar ou comparar a relevância ou improvement da utilização de tecnologia digital atualmente utilizada em Medicina Dentária, do diagnóstico ao follow-up, dado que esta é economicamente dispendiosa e requer uma curva de aprendizagem demorada e exigente. De uma forma objetiva pretende-se responder à questão: será que a aplicação da tecnologia digital otimiza as reabilitações orais dos pacientes em comparação com os métodos analógicos convencionais?

Objetivos:

- Analisar a qualidade da reabilitação oral final de acordo com a guia cirúrgica digital utilizada;
- Analisar a qualidade da reabilitação oral final de acordo com o protocolo cirúrgico de fresagem de implantes dentários através de guias cirúrgicas computorizadas;
- Analisar a qualidade da reabilitação oral final de acordo com o protocolo cirúrgico de manipulação de tecidos moles em cirurgia periodontal / implantar;
- Analisar a qualidade da reabilitação oral final de acordo com o processo de fabrico digital da reabilitação oral protética e materiais utilizados;
- Analisar a posição real 3D do implante em relação ao planeado em software de planeamento;
- Analisar a estabilidade peri-implantar obtida em função de diferentes protocolos cirúrgicos e (bio)materiais utilizados;
- Analisar parâmetros de avaliação digital oclusal utilizados na reabilitação oral protética.

Tipo de estudo: Estudo Clínico Sem Intervenção (em concordância com a lei n.º 21/2014 de 16 de abril). Estudo Observacional Longitudinal (retrospetivo).
Locais onde decorre o estudo: Faculdade de Medicina Dentária da Universidade Católica Portuguesa.
População: A amostra será obtida a partir da população de pacientes que frequenta habitualmente a Clínica Dentária Universitária da FMD-UCP, que tenham realizado reabilitação oral, e que tenham no seu registo clínico as informações necessárias (variáveis em análise – descritas no Anexo I).
Não envolve menores, nem populações vulneráveis.
Instrumento de colheita de dados: Os dados referentes às variáveis em análise (descritas no Anexo I) serão introduzidos numa base de dados de SPSS totalmente anonimizados.
Procedimentos: O investigador principal solicitará ao RGPD da Faculdade de Medicina Dentária da UCP (Prof. Doutor Paulo Ribeiro) os dados referentes às variáveis em análise (Anexo I), devidamente anonimizados, antes de distribuir para análise pelos restantes elementos da equipa de investigação.
Riscos ou incómodos: Tratando-se de um estudo retrospetivo com base em dados obtidos do RGPD já anonimizados, não representa qualquer risco ou incómodo para os pacientes.
Potenciais benefícios: Tratando-se de um estudo retrospetivo com base em dados obtidos do RGPD já anonimizados, os benefícios são indiretos e para futuras intervenções clínicas em outros pacientes.
Confidencialidade dos dados e RGPD: A confidencialidade e anonimato dos dados é garantida pelo RGPD (Prof. Doutor Paulo Ribeiro) que entrega ao investigador principal os dados referentes às variáveis em análise, garantindo a não identificação do paciente. Apenas o RGPD terá acesso a uma chave de anonimização. Os dados solicitados ao RGPD são registados e armazenados num computador da Faculdade de Medicina Dentária destinado para o efeito, com acesso protegido e apenas durante o estudo, pelo Investigador Responsável. Concluída a investigação, os dados armazenados serão eliminados.
Autorização da Instituição/Instituições onde vai decorrer o estudo: apresentada.
Valor científico e social: A investigação proposta apresenta valor científico e social. O desenho do estudo apresenta valor social, científico e clínico, com potencial para ganhos na área da saúde oral – reabilitação oral - e do atendimento personalizado. Do ponto de vista metodológico revela rigor e robustez na fundamentação.
Integridade, transparência e idoneidade: As declarações de Conflito de interesses são apresentadas. Os *CV´s* da equipa de investigação revelam a idoneidade para a prossecução da investigação em causa e adequação à natureza do estudo. As fontes bibliográficas estão devidamente apresentadas.

Estiveram presentes na reunião nº 38 da CES-UCP
Presidente: Doutora Mara de Sousa Freitas
Doutor Jerónimo Santos Trigo
Doutor Pedro Garcia Marques
Dr. Eugénio Fonseca
Doutora Ana Mineiro Zaky
Doutora Marta Brites
Mestre Ivone Gaspar

Conclusão
Ouvido o Relator, e o plenário da reunião de 24 de março de 2022, realizada por videoconferência, esta CES delibera, por unanimidade, emitir **Parecer Favorável**.

Esta CES solicita ao Investigador Principal que, aquando da conclusão do estudo, lhe seja enviada uma síntese dos resultados obtidos e respetivas conclusões, via eletrónica, para o correio eletrónico da CES UCP.

A Presidente,

____

Mara de Sousa Freitas
24/03/2022

Membros do Júri das Provas Públicas

Presidente: _________Dr. Professor Cristina Figueredo________

(Categoria profissional e Filiação académica)

Arguente: ______ Dr. Professor Helena Salgado______

(Categoria profissional e Filiação académica)

Orientador: ____ Dr. Professor Tiago Miguel Santos Marques_____

(Categoria profissional e Filiação académica)

Data das provas públicas: 19 / 07 / 2024

Validação e confirmação pelos serviços escolares:

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___ / ___ / ___