GRADUATION PROJECT

Degree in Dentistry

Greater and lesser palatine nerves: anatomical variations and its relevance on clinical practice

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RESUMEN:

Introducción: El conocimiento correcto y completo de la anatomía humana es el principio básico de la medicina moderna, en todo tipo de especialidades y campos. La odontología no es una excepción, especialmente cuando se consideran los numerosos tipos de intervenciones quirúrgicas de diversa magnitud que se pueden realizar para una variedad de tratamientos. Como tal, los nervios palatinos mayor y menor se consideran componentes clave para la práctica dental. **Metodología y Objectivos:** esta revisión tiene como objetivo revisar la literatura científica sobre la anatomía de los nervios palatinos mayor y menor y de sus estructuras circundantes y asociadas, con el fin de evaluar las variabilidades encontradas en la población general, así como las técnicas que permiten evaluaciones anatómicas preventivas precisas de tales variaciones potenciales. **Resultados:** Los estudios realizados en una variedad de poblaciones y ubicaciones geográficas han demostrado que las estructuras de los nervios palatinos mayor y menor no son homogéneas, y de hecho presentan una gran variedad de variabilidades, ya sea por género, edad, lados observados, cara. patrones morfológicos y etnias. **Discusión:** Estas variabilidades, si se ignoran, aumentan los posibles riesgos iatrogénicos para nuestros pacientes y, por lo tanto, deben ser consideradas. De forma paralela, la observación y el estudio de las características anatómicas faciales humanas se ha vuelto cada vez más accesible, precisa y eficaz debido al desarrollo relativamente reciente de las técnicas de imagen tridimensional, en particular en forma de materiales de tomografía computarizada de haz cónico y materiales asociados. metodología. **Conclusión:** Los descubrimientos y confirmaciones de la existencia de variaciones anatómicas en la anatomía humana de los nervios palatinos mayor y menor representan un desafío para el odontólogo que realiza tratamientos que involucran estas estructuras particulares. Sin embargo, la cada vez mayor accesibilidad a técnicas de imagen más avanzadas y rentables que permiten el estudio con gran precisión de estos puntos de referencia permiten responder adecuadamente a cualquier tipo de características anatómicas que puedan presentar nuestros pacientes.

Palabras clave: Odontología, nervios palatinos mayor y menor, variabilidades anatómicas, mejora de la seguridad del tratamiento

ABSTRACT:

Introduction: The correct and thorough knowledge of the human anatomy is the core tenet of modern medicine, in every type of specialties and fields. Dentistry is no exception, notably when considering the numerous types of surgical interventions of various magnitude that can be perform for a variety of treatments. As such, the greater and lesser palatine nerves are considered as key components for the dental practice; **Methodology and Objectives:** This review aims to revise the scientific literature regarding the greater and lesser palatine nerves anatomy and that of their surrounding and associated structures, in order to assess variabilities encountered in the general population as well as techniques permitting precise pre-emptive anatomical assessments of such potential variations; **Results:** Studies realised in a variety of populations and geographical locations have shown that the structures of the greater and lesser palatine nerves are not homogeneous, and present in fact a great array of variabilities, be it by gender, age, observed sides, facial morphological patterns, and ethnicities; **Discussion:** These variabilities, if ignored, increase the potential iatrogenic risks for our patients, and must therefore be considered. In a parallel way, the observation and study of the human facial anatomical characteristics has been rendered increasingly more accessible, precise and effective due to the relatively recent development of three-dimensional imagery techniques, notably in the form of Cone Beam Computerised Tomography materials and associated methodology; **Conclusion:** The discoveries and confirmations of the existence of anatomical variations in the human anatomy of the greater and lesser palatine nerves pose a challenge for the dental practitioner performing treatments involving these particular structures. However, the ever-increasing accessibility of more advanced and cost-effective imagery techniques permitting the study with great precision of these landmarks allow to respond appropriately to any type of anatomical characteristics that our patients may present.

Keywords: Dentistry, greater and lesser palatine nerves, anatomical variabilities, treatment safety improvement.

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1. INTRODUCTION:

1.1. The knowledge of the human anatomy:

The knowledge of the human anatomy and physiology is one of, if not the most important basis of modern medicine. It is the foundation of the contemporary approach of the practice, a basis that every medical fields rely on. The pursuit of a comprehensive and precise understanding of the human body is not a recent endeavour. Anatomical studies have historically been conducted since the ancient world, throughout the medieval, renaissance and classical period. The knowledge has gradually refined itself, but has had to wait up until fairly recently for the extensive breakthrough, and for the spreading and easy access of these discoveries.

The book of Henry Gray and Henry Vandyke Carter: Gray's Anatomy, is a prime example of such advancement, taking place during the booming of medical and scientific discoveries that will pave the way for the creation of the modern medicine concept. Published in 1858 and becoming throughout the 20th a worldwide reference, this compilation of studies and observations compiled in a comprehensive and accessible anatomy and physiology book can be considered as one of the reflections of the pillar of the modern-day medicine that is anatomy. (1)

This work underlines the major importance of the comprehension in its totality of the human anatomy and physiology by the medical practitioner regardless of his specialisation. This concept naturally applies to Odontology and all of its specialised fields, especially regarding surgical procedures. It is indeed the way of performing safe, reproducible and successful interventions. (1)

The greater, lesser palatine nerves as well as the palatine canal and foramina are key anatomical structures regarding dentistry. Indeed, a wide array of dental procedures on the maxillary region must take into consideration the placement and localization of these nerves and their neighbouring structures. (2)

To accommodate these necessities, the general characteristics of the anatomy of the greater and lesser palatine nerves have been studied and reported in numerous literatures. These descriptions have led to the improvement of the surgical guidelines such as for teeth extractions and implant placement, as well as sedative techniques using increasingly adapted landmarks for anaesthesia injections. (2–7)

1.2. The greater and lesser palatine nerves; understanding key anatomical structures in clinical dentistry:

As a general rule, the greater and lesser palatine nerves (GPN and LPN) and their respective palatine foramina have been described in the literature as being in the following anatomical disposition:
The GPN and LPN nerves find their origin from the parasympathetic pterygopalatine ganglion, located in the Pterygopalatine fossa, posteriorly to the middle nasal turbinate and the maxillary sinus. (1–3,5,6,8)

The pterygopalatine ganglion is associated with the Maxillary nerve, who himself originates from the trigeminal ganglion.
The GPN descends by the greater palatine canal (GPC) as a unified trunk up until it reaches the exit of the palatine canal, the greater palatine foramen (GPF). (1–6) It travels onto the bony surface of the hard palate within a groove splitting into several branches covering the periosteum and the palatine osseous surface. (1–6)
It usually communicates with the nasopalatine nerve on its terminal filaments, as it ends short from the maxillary incisors crowns and roots. (1,2,4–6)

The GPF is generally encountered next to the lateral hard palate border, in the posterior-lateral border, medially to the 3rd maxillary molars, or oppositely to the 3rd maxillary molars. (1,2,5,7,8)
The GPN innervates both the mucosal parts of the hard palate, the gingival tissue as well as the glands. (1,2,4–7)

The LPN goes through the GPC and emerges from the lesser palatine foramen, posteriorly to the GPN. It supplies the soft palate, the palato-pharyngeal region, the uvula, the palatine levator veli muscle, the tonsils as well as the palatine glandular tissues. As such, it is an important structure regarding the capabilities of speech and deglutition process. (1,2,5,9)

1.3. The greater and lesser palatine nerves as key anatomical structures for clinical dentistry:

The procedures concerned by the physiology of the palatine nerves are numerous, diverse, and cover for a large array of odontology and medical specialized fields. They include: maxilla-facial surgery, dental surgery, periodontal dentistry, and implantology. (2–7,10)

This type of interventions requires a correct knowledge of the nerve's anatomy, for multiple reasons:

1.3.1. The necessity of performing a correct anaesthesia placement:

Anaesthesia techniques are an important point when discussing the role of the GPN and LPN. Certain techniques and application in particular have an important relevance concerning these nerves, both directly and indirectly, in dentistry but also in certain maxilla-facial surgery procedures:

- **Greater palatine nerve block:**

This technique concerns directly the GPN. It can be used in a variety of procedures:

- Restorative treatments on more than two teeth. It is usually not necessary on treatments implying one tooth only. (2)
- Control of the dolour for periodontal or oral surgical procedures implying the soft and hard tissues of the palate. (2,11)
- Specific usage: Palatoplasty for patient suffering from cleft palate defect. (2,4,6)

It must be taken into consideration that this technique should not be used in case of infection or inflamed tissues on the site. (2)
In general, this technique is used for procedures involving the soft tissues of the palate from the 3rd molar to the distal surface of the canine. It anesthetizes the posterior hard palate and its soft tissues. Its effect is also limited by the middle line of the palate. (2,4,6,7)

This technique presents a common usage, notably due to the small amount of anesthetic product necessary to achieve a positive result.(2) Usually, few discomfort is reported by patients.(2) As well, the alternates techniques can be more difficult to put in place (such as with the maxillary nerve block) or cause an increased patient discomfort (such with the use of multiple infiltrative injections) (7). Finally, failure of the injection is not common.(2) However, the hemostatic effect is low, and the procedure itself has an iatrogenic risk. (2,6)

The landmarks and target are important to consider: the dentist must aim for the GPN passing anteriorly using the landmarks of: the GPF itself, the junction zone of the alveolar process of the maxilla, and the hard palate bone. (2,6)

- **The Maxillary nerve block:**

While this technique does not specifically aim for the GPN nor the LPN, they and the associated GPC are indirectly implied when this technique is performed, since the maxillary nerve block can be realized by using a GPC approach. (2,5,7)

This technique is used to perform an effective hemi maxillary anesthesia, by numbing the trigeminal nerve maxillary division (V2).(2,5,7) More precisely, it anesthetizes directly the pulp of all of the teeth of the selected quadrant, the bone and soft tissues of the buccal and hard palatine areas up to the middle line of the palate.(2) Extra orally, it also numbs the skin of the inferior eyelid, the lateral part of the nose as well as the superior part of the lip. (2,5,7)

Usually, this technique is reserved for procedures implying:

- Periodontal treatment on full quadrants. (2,7)
- Surgery treatments, notably for bleeding control, teeth extraction, abscess drainage. (2,3,5,7)
- Endoscopic surgeries, septorhinoplasties. (2,7)
- It may also be considered during certain specific situations in place of other techniques, such as for example if the patient is suffering from an inflammation or an infection of the tissues preventing the dentist form using other less invasive anaesthetic techniques. (2,5,7)

Interestingly, more specific usages include the use of this technique in the diagnostic and therapy of trigeminal neuralgia (implying the maxillary branch of the trigeminal nerve). (2)

This technique is regarded as being effective and generally atraumatic when being performed by an experienced operator. (2,5,7) One of its advantages is the fact that an hemi maxilla anaesthesia can be achieved by using only one point of injection, with a reduced load of anaesthetic product compared to other approach. (2,7)

However, the success of the GPC approach of the maxillary nerve block is highly dependent on the skill and experience of the dentist, and trauma (although generally low in occurrences) are still possible. (2,3,5,7)

Certain conditions may limit or prohibit this technique: GPF inflammation, Paediatric patients or individuals not showing cooperation prevent this approach. Also, obstruction of the GPC may be present, at rates going as high as 15%. (2,3,5)

1.3.2. The requirement of avoiding at all cost damage to the nerve's terminations:

This particular point is especially relevant for implant surgery, surgical teeth extractions, all procedures requiring a flap elevation, endoscopic sinus treatments, Lefort I osteotomies and anaesthesia placement. (2,4,7,10,12)

- In implant surgery and surgical teeth extractions, an important aspect to consider is the placement of the greater and lesser palatine nerves ramifications as they may be placed closed to the tooth to extract of to the implant placement site. (3,5)

- Flap elevation, necessary for grafting technique and for certain cases of surgical teeth extractions, if done carelessly with no considerations for these ramifications, may also cause neurological damage. As incisions should of course avoid to cross over the nerves' terminations, understanding their courses is critical to

avoid potentially irreversible injuries, and assure a safe and controlled surgical treatment. (4,5)

- Endoscopic sinus surgery as an alternative for the treatment of sinus diseases is a procedure that has become more common in the last two decades. (3,4,8) This surgical approach can for example be used for the treatments of angio-fibromas and can permit a safer access to the sphenoid air cells with a reduced risk of damaging the pterygopalatine fossa anatomical structures, such as the infra-orbital nerve, as the trans-antral technique.
However, this procedure can present complications linked to the palatal nerves. Palatal iatrogenic anesthesia is an example of a possible complication that can be reported after this endoscopic sinus surgery, due to an injury of the GPN. (4,8)

- Osteotomies can involve the palate anatomical area and may concern the greater and lesser palatine nerves. The Lefort osteotomy type I is an example; (10)

This procedure is indicated for the correction of classes II and III maxillary and mandibular malocclusions, dento-facial asymmetries, midface hypoplasic development, maxillary vertical overgrowth, maxillary atrophy, obstructive sleep apnea, and pre-operation for implant placements in atrophic maxilla and mandible. (10,12)

The procedure consists in the separation of the maxilla and subsequent repositioning. It can be used in combination of a distraction osteogenesis. (12)

This surgical technique although one the most commonly used is subject to possible neurological complications involving the greater palatine nerve through iatrogenic damages during the operation. (10)

Previous knowledge of the anatomical references of each individual patients is therefore a must have requirement in order to avoid iatrogenic consequences, and to perform a successful maxillary position correction. (4,10,12)

1.3.3. The need of knowing which structures are innervated or not by the palatine nerves:

This question is essential to keep in mind, as nerves endings dictate what structures will be concerned or not by the anaesthetic injections or if they will be included in the surgical field. (2,5–7)
This way, the practitioner is assured to perform the most conservative, effective and less traumatic as possible operation on his patients. (2,5–7)

1.4. Risks factors existing when performing procedures on the palatine nerves:

Interventions implying the greater and lesser palatine nerves include a series of risks factors that must be taken into consideration, in order to avoid possible iatrogenic effect on patients. Anatomical particularities encountered on certain patients increase the risks of such failure or incidents if not considered beforehand. (5,7) These risks factors are multiple and concern a variety of interventions and types of treatments:

- Anaesthesia failure:

Incorrect knowledge of anatomical region aimed for may manifest itself in the form of a partial or total failure for the anaesthesia to take effect. (2,5)

The maxillary nerve block technique using the GPC approach can fail when the length of the canal or the GPF position are not well appreciated beforehand by the dentist. (2,5,7)

Assessing correctly the length of the canal is primordial, especially when considering that failure of anaesthesia is a rather common issue encountered when performing this particular technique, which has led for a time to a loss of popularity of the procedure. Using pre-determined landmarks to assess the size can be insufficient, considering the large variance of the GPC length reported is the literature. (2,5–7)

- Accidental anaesthesia:

Accidental anaesthesia to another anatomical target is also possible.

The GPN block technique is an example: when performed with the needle tip placed too posteriorly in regards to the GPF thus reaching the LPF, accidental anaesthesia of the LPN may occur. (2)

In turns, the patient may suffer from a gag reflex due to the anaesthesia of the soft palate. (2)

The maxillary nerve block using the GPC way can also induce accidental anaesthesia of a variety of anatomical structures, with immediate or longer lasting consequences potentially severe for the patient's health. This is also due to lack of knowledge of the GPC anatomical characteristics and length. (2,4,5,13)

Among these complications are:

Ptosis by anaesthetic reaching the oculomotor nerve, strabismus, diplopia due to anaesthesia of the abducens nerve, ophthalmoplegia, anaesthesia of the orbital and/or ocular nerve, anaesthetic penetration of the nasopharynx region, intravascular injection, temporary blindness from the constriction of the ophthalmic nerve, and Intracranial propagation of the anaesthetic solution trough the foramen rotundum, inducing possible unconsciousness of the patient. (2,3,5,8,13)

- Anaesthesia related iatrogenesis:

Anaesthesia failure or unwanted anaesthesia of other anatomical sites, while problematic, are not the only problem that may arise. Injuries due to wrong placement of the needle may occur when performing the GPN block and the maxillary nerve block.(2,4,13)

Example of such injuries are:

localized hematoma, Infra-orbital nerve injury, long lasting paresthesia due to trauma affecting the maxillary nerve or GPN, traumatic neuroma located in the palatal site of the GPF, or needle breakage inside of the GPC. (2–5,13,14)

- Surgical risks:

Surgical techniques implying the GPN and LPN have to be performed with extreme care, to avoid possible injuries with long term consequences. (4,5,9)

Applying incisions, the superficial palatal membrane may sever the GPN if the anatomy is not carefully considered beforehand. (4)

Le Fort type 1, endoscopic, sinonasal surgeries, upper molar extractions, orthodontic type implant placements, cysts and tumor excisions and graft tissue collection procedures are also not risks-free interventions, due to accidental dissection of the GPN. (3,4,10)

During the Le Fort 1 surgical procedure, the GPN must be protected with a Freer instrument. Knowledge of the anatomical landmarks is, once again, a key element. (10)

Regarding the LPN, protection of its structures is important as well during cleft palate correction, as the nerve possesses an important role in the subsequent speech recovery of the patient. (9,15)

1.5. The existence and implications of anatomical variabilities in the greater and lesser palatine nerves:

The anatomy of the GPN and LPN as well as their associated structures such as the GPC, GPF and LPF is not homogeneous:

There is a tendency emerging from past researches, reviews and anatomical books that is to be remarked, in that the anatomy of the GPN and LPN and related structures used to be described in a rather homogeneous and monolithic way. (7)

As a logical consequence, landmarks commonly used for techniques of anesthesia as well as guidelines for surgical procedures follow these general anatomical descriptions, and tend in turn to be rather broad and impersonal. (7)

It seems that while the descriptions made in the past anatomical analysis are on average correct, there is a certain range of variability regarding the anatomical disposition and characteristics of the GPN, GPC, LPN, GPF and LPF(4,16)

These variabilities are manifold, and are, in addition, susceptible of only appearing at certain ages, facial types, in some acquired of inherited medical conditions, or in certain populations. (3,5,7,8,17–36)

The use of general anatomical landmarks is still a norm, notably for anesthetic procedures, in the clinical practice. (2)

Subsequently, it has been observed in the dental clinical environment a possible occurrence of injuries and/or iatrogenic effects, due to a miss interpretation of the anatomy in specific patients. (2,4,5,7)

1.6. The necessity of finding and applying methods for a safer approach of the palatine nerves:

The search for safer and easier medical methods and techniques naturally applies for the procedures implying palatine nerves.

The usual response to such potential risks and problems has been narrow. In the case of a possible anaesthesia failure, the most common guideline has traditionally been to re-inject an anaesthetic dose in order to achieve the researched effect. This is however of a limited effect as such re-anaesthesia might still fail since the correct position of the greater and lesser foramina of the palatal nerves can still be not known. Moreover, it might not be welcomed by patients. (7)

The reports as well as the past reviews showing that a certain rate of anaesthetic injections or surgical interventions, using theoretically correct landmarks and techniques, fail to deliver the desire effect on some patients, demonstrate that a more profound consideration could be given to these anatomical variations.

While the classically used techniques and anatomical landmarks already permit correct interventions, it is necessary to improve the safety and success of treatments implying the GPN and LPN, to further reduce the incidence of the potential risk factors.(3,4,7,9,16)

In the last two decades, methods and new technologies have been studied in order to, on one hand, reduce the potential iatrogenesis to interventions on palatine nerves, and on the other hand to facilitates the dental practices involving these structures.(3,4) Based on the relatively numerous occurrences of technique failures and iatrogenesis, questions arise as to how an improvement of the success rate of interventions involving the greater and lesser palatal nerves could be achieved with readily available techniques and equipment ? And what is the exact level of presence and influence of those anatomical variations observed in some patients population ?

2. REVIEW OBJECTIVES:

The objectives of this review will be therefore to achieve a precise description of the anatomical variations of the lesser and greater palatine nerves encountered in the general population, compared between specific groups regarding palatal sides, age, ethnicity, and its subsequent relevance in the odontological protocols, in common or specific dental procedures.

This review also aims to investigate specific techniques and material usage that could have a use to precisely locate palatine nerves terminations and foramina to aid dental practitioners in general or specific dental procedures, with a specific focus being put on reliability, ease of use and effectiveness.

It seems reasonable to expect from this review the confirmation that physiological differences in the palatine nerves dispositions have indeed an influence on the success rate of anaesthesia procedures in common dental practice, and that techniques available to easily locate correct anatomical landmarks are necessary to accomplish our treatments with an always safer and more effective methodology

3. MATERIAL AND METHODS:

3.1. Data bases used for this work:

Multiple data bases have been used to conduct this review work:

– Online scientific data bases for the search of scientific articles: Pubmed, Research gate. The bibliographical contents of each article were in turn reviewed in search for further articles of interest.

– Online books and scientific journals.

3.2. Eligibility criteria:

3.2.1. Inclusion criteria:

Articles were selected according to a list of criteria permitting a precise and thorough research of the subject:

– Articles related to the anatomical description and variabilities of the GPN, LPN, GPF, LPF and GPC.

– Articles related to dental interventions or techniques related to the GPN, LPN, GPF, LPF and GPC.

– Articles could be selected from a variety of countries and institutes to include a diverse and comprehensive source.

– Articles were preferably selected in English, Spanish and French, but articles in other languages were also accepted provided a correct translation

– Articles selected could be in physical or electronic format.

– Articles and books selected had a publication dating from a maximum of 30 years old.

3.2.2. Exclusion criteria:

– Articles, journals or books without any link to the subject were not selected

– Articles, journals or books having a link to the subject but with no citations or sources were discarded.

– Sources found written in a foreign language other than French, English or Spanish in a non-translatable format were not chosen.

– Sources originating from non-verified data bases or websites were excluded.

3.2.3. Specific key words used for the online research:

The specific key words used were chosen in relation with the subject and had the objectives of permitting precise research.

Greater palatine nerve, Lesser palatine nerve, Greater palatal foramen, Lesser palatal foramen, Anatomy, Orthognathic surgery, Lefort I osteotomy, Post operative complications.

Research combinations used:

Pubmed:

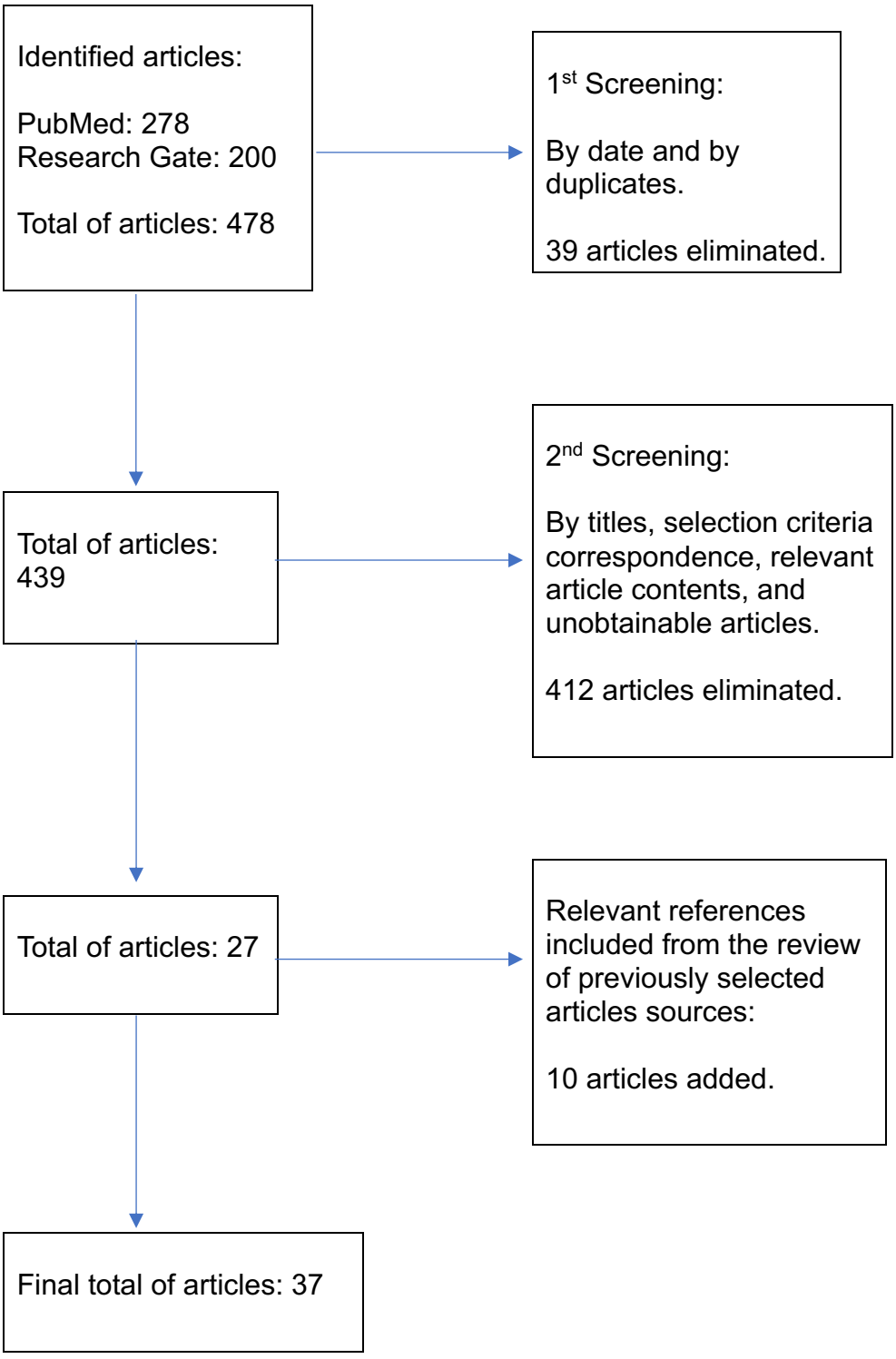
- (((Greater palatine nerve) AND (lesser palatine nerve)) OR (greater palatine nerve)) OR (lesser palatine nerve).
- (Greater palatine foramen) OR (lesser palatine foramen)

Reserchgate:

- (Greater and lesser palatine nerve foramina) AND (anatomy)
- (Orthognathic surgery) AND (Lefort I osteotomy) AND (Postoperative complications)

The total of retained articles used for this review was 37.

3.3. Articles research flowchart



4. RESULTS:

Table 1: data extracted from the articles analysed

Article:	Study:	Results:	Results (bis):
Gray et al 2015	General human anatomy.	Description of the maxillary nerve, GPN, LPN anatomies.	
Article:	**Study:**	**Results:**	
Malamed et al 2020	General techniques for local dental anaesthesia.	Anatomical description of the maxillary nerve, GPN and LPN. Description of the GPN and maxillary nerve block procedures.	
Article:	**Study:**	**Results:**	**Results (bis):**
Howard-Swirzinski K et al 2010	CBCT study of the anatomy of the GPC. Comparison with other studies Analysis: 500 individuals. 265 females, 235 males. Age: 18 to 73 years old.	GPC length: 29mm mean, 22-40mm range. Recommended depth for injections: 25mm for sinuses haemostatic measure, 32 to 39mm for maxillary nerve block.	GPC direction: Coronal view: Inferolateral, inferior: 43.30% Symmetry: 22% Sagittal view: anteroinferior: 92.2% Symmetry: 88% Higher variations encountered in the mediolateral direction between sides.

Table 1: data extracted from the articles analysed

Article :	Study:	Analysis:	Results:
Hafeez NS et al 2015	Study of the GPN on dissected cadavers.	20 subjects, 9 females and 11 males, of normal anatomy.	5 different branching paths were observed.
Article:	Study:	Results:	Results (bis):
Sharma et al 2013	Study of the GPF position, with adjacent landmarks. Analysis: 100 Indian skulls.	GPF-Middle maxillary suture, GPF-Incise foramen, GPF-Posterior Hard Palate Border measures, GPF diameter: No relevant side by side differences. GPF-Pterygoid hamulus: Significant differences between sides.	GPF orientation: anteromedial position majority. GPF to maxillary molars: palatal to the 3rd molar position majority. One case with absence of GPF and LPF LPF number: from 0 to 5. Average: 1.39 on the right, 1.43 on the left.
Article:	Study:	Analysis:	Results:
Sundar et al 2020	Study of the effects of the GPN block for the anterior palate anaesthesia.	Testing conducted on 100 subjects, 45 men, 55 women, needing posterior and anterior teeth extraction. Age: older than 18 years old. Mean: 52 years old.	Positive response to the anaesthesia: 84 out of 100 subjects reported effective anterior numbing of various range. The technique is reported as effective for anterior teeth anaesthesia.

Table 1: data extracted from the articles analysed

Article:	Study:	Results:	Results (bis):
Chrcanovic BR et al 2010	GPF position to palatine landmarks. Analysis: 80 Brazilian skulls.	GPF opening: anteriorly for the majority. GPF – maxillary molars: majority: Distal to the 3rd maxillary molars	No significant differences noted between genders in measures of GPF-MMS, GPF-IF, GPF-PHPB, GPF-IF line to MMS angle.
Article:	Study:	Analysis:	Results:
Das S et al 2006	High Resolution CT study of the GPC, for GPF anaesthesia in sinus surgical procedures.	100 adult patients, half males and females. 1300 images. Comparison with other studies.	Injection in the GPC of 25mm of depth and 60° angle recommended. GPF-SPF and GPF-OF measures: No relevant side by side variations.
Article :	Study:	Analysis:	Results:
Mu L et al 2020	Soft palate innervation. Study of the soft palate, pharynx, larynx, tongue.	6 subjects, 3 men and 3 women. Age: 51 to 79 years old. Median 65 years old Normal Musculo-skeletal anatomy.	The LPN innervates the palate mucosa, the glandular tissues, the muscles of the uvula, the palatopharyngeus and levator levi palatine, suggesting new options for sleep apnoea and neuromodulation therapies.

Table 1: data extracted from the articles analysed

Article :	Study:		Results:
Dabir A et al 2021	Description of the maxillary region anatomy and the Lefort type 1 technique, applications, with reports of clinical cases		The maxillary region nerves are at risks during surgical procedures. A freer instrument can be used to shield the GPN. CAD-CAM permit landmarks assessment.
Article:	Study:	Analysis:	Results:
Manjunath RK et al 2009	Comparison of the GPN block and I.V Pethidine for post operation pain management.	50 children of less than 10 years old. Two groups: I.V Pethidine and GPN block.	GPN block is considered more useful, efficient and effective. Less deep numbing effect, patient discomfort and need for re anaesthesia.
Article:	Study:		Results:
Buchanan et al 2013	Lefort type 1 technique		Knowledge of anatomical landmarks is essential to avoid iatrogenesis.

Table 1: data extracted from the articles analysed

Article :	Study:	Results:	Results(bis):
Sved A et al 1992	Complications of the GPC maxillary nerve block technique. Analysis: 101 patients from 9 to 84 years old with a mean of 30 to 39 years old individuals. 7 dentists reporting of each incident.	Occurrences: 10 ptosis 12 strabismus 1 neural trauma 36 diplopia 8 blood aspiration 6 GPC constrictions 11 anaesthetic failures: 6 partials, 5 total.	11 anaesthetic failures: 6 partials, 5 total. Anaesthetic success rate: 89.1% The approach is overall considered safe and effective.
Article :	Study:	Analysis:	Results:
Eguchi T et al 2016	Description of a palatal neuroma.	One Japanese thirty years old patient.	Traumatic neuroma is rare but can occur on the palate. While not in this case, surgical of trauma events are usually responsible. Treatment consists of an excision.
Article :	Study:	Analysis:	Results:
Kishimoto H et al 2016	Determine the GPN implication in the levator veli palatini innervation.	Patients necessitating cleft palate palatoplasty surgery. 3 male patients, of 10, 11 and 12 years old.	Confirmation of the GPN implication in the levator veli palatini innervation, and role on speech recovery.

Table 1: data extracted from the articles analysed

Article:	Study:	Results:	Results (bis):
Kageyama I et al 2021	Maxillo facial nerves and arteries comparative description with previous studies.	The GPN is superficial to the GPA. Anatomical variabilities are common in the general population.	
Article :	Study:	Results:	Results (bis):
Kumar A et al 2016	Position of the GPF Number of LPF Palatine width, height and length Analysis: 86 Indian dried skulls, of normal anatomies. Period: 2007-2010	Between genders: High differences in palatine length and width, few in palatine height.	GPF position: 3rd molar majority. High 2nd and 3rd molar rate. Rare occurrences of 2nd and 3rd molar positions. LPF: 1 for the majority. Maximum number: 3
Article :	Study:	Results:	Results:
Kumar A et al 2011	Anatomical characteristics of the GPF in Indian subjects, to aid in maxillary nerve blocks. Comparison with other studies. Analysis: 100 normal skulls	GPF position: majority: oppositely to the 3rd molar. GPF orientation: majority: antero-lateral LPF mean number: 1.2 on the right, 1.3 on the left	No relevant discrepancies between sides in GPF to MMS, IF and PHPB distances, GPF position, nor in LPF number.

Table 1: data extracted from the articles analysed

Article :	Study:	Analysis:	Results:
Thunyacharoen S. et al. 2021	Distances from landmarks to GPF, LPF and IF.	200 Thai skulls, half males and females of normal anatomy.	IF to GPF and IF to LPF: Statistically significant differences between genders. Higher values in males. GPF position: Medial to 3rd maxillary molar in majority, especially in males
Article :	Study:	Analysis:	Results:
Lacerda et al 2022	CBCT study of the GPF on different facial types.	60 subjects, dolicho, meso and brachyfacial, older than 18 years old.	Variations observed between facial types in the position of the GPF to the maxillary molars and adjacent palatine landmarks.
Article :	Study:	Analysis:	Results:
Aoun G et al 2016	CBCT study of the GPC and pterygopalatine fossa anatomy.	79 Lebanese subjects, 38 females, 41 males.	Curvature of the GPC observed in the majority of subjects. Minor side and gender differences in GPC length, diameter, anatomy.

Table 1: data extracted from the articles analysed

Article :	Study:	Analysis:	Results:
Jalalian F et al 2013	CBCT study of the GPC length and course.	138 Iranian subjects, 65 females, 73 men, of normal anatomy.	GPC length: differences were noted between sides and Genders. No relevant differences according to age.
Article:	Study:	Analysis:	Results:
Bahsi et al 2019	Morphometric CBCT study of the GPF, GPC and pterygopalatine fossa, using 8 sagittal and 11 axial measures to multiple landmarks	150 subjects, half males and females. Age: 18 to 65 years old. Normal anatomy.	Number of LPF: similar between genders and side. Genders variations were noted in the following measures: GPF-Pterygoid canal LPF-GPF GPF-occlusal plane GPF-midsagittal plane GPF-PNS GPF-IF Diameter of the GPF

Table 1: data extracted from the articles analysed

Article :	Study:	Results:	Results (bis):
Aoun G et al 2015	Review of the maxillary nerve through the GPC technique. Comparison of the GPF location to MMS, PHPB, and maxillary molars, between theoretical landmarks and positions find on different populations.	Differences noted in the repartition and frequency of the GPF positions to the molars between populations. In all populations: 3rd molar position prevalence.	GPC length on CBCT: Differences were noted, with a few millimetres of margins. Differences were noted in the GPF-MMS and GPF-PHPB measures.
Article :	Study:	Results:	Results (bis):
Saralaya V et al 2007	Study of the GPF localization for dental maxillofacial surgical procedures anaesthesia. Analysis: 132 Indian subjects of normal anatomy.	GPF-IF line to midpalate suture angle: Significant side variations noted. GPF-IF: no significant side variations. Position of the GPF to the molars: Higher occurrence of oppositely to the 3rd molar position. No significant side variations.	GPF direction: Medial forward and forward directions prevalence. LPF: symmetry in 40% of the cases. No significant side variations.

Table 1: data extracted from the articles analysed

Article :	Study:	Results:	Results (bis):
Piagkou M et al 2011	Study of GPF and LPF anatomical variations in Greek subjects, and comparison to other studies. Analysis: 71 skulls of normal anatomy.	GPF to maxillary molars: proximal-distal of the 3rd molars position majority No relevant sides difference. GPF- MMS, GPF-AR, GPF-PHPB, GPF diameter measures: no relevant differences between sides.	LPF position: Between the palatal bone and pterygoid plate (majority) LPF-MMS, LPF-PHPB: no relevant differences between sides. LPF number: Higher frequency: 1, maximum: 3. Differences noted between sides.
Article :	Study:	Results:	Results (bis):
Souza A et al 2012	Anatomical study of the hard palate including the GPF in Indian subjects. Comparison with other studies. Analysis: 40 skulls of normal anatomy.	GPF position to the maxillary molars: Majority: oppositely to the 3rd molar. Others (in frequency order): Between 2nd and 3rd molar, oppositely to the 2nd molar	GPF-MMS: variations noted from other populations. LPF number: Majority: 1 Maximum: 3

Table 1: data extracted from the articles analysed

Article :	Study:	Results:	Results (bis):
Sarilita et al 2015	Study of the hard palate anatomy, including GPF and LPF. Observation of the distance of the GPF and LPF to adjacent anatomical landmarks. Analysis: 63 Indian skulls. Comparison with other studies.	GPF shape: Majority: oval. GPF position to maxillary molars: Majority: oppositely to the 3rd molars. Others (by frequency): between 3rd and 2nd molars, oppositely to the 2nd molar	LPF shape: lancet and oval at equal rate. LPF numbers: 1 to 6. 68%: more than 1. Asymmetry: 4.30 to 18.30% Significant statistical sides difference in GPF-PteH measure.
Article :	**Study:**	**Results:**	**Results (bis):**
Nimigean V et al 2013	Anatomical study of the GPF. Comparison with other populations and studies. Analysis: 100 Caucasian skulls. 25 partial edentulous.	GPF shape: oval in majority GPF-maxillary molars position: majority: internal to the 3rd molar. Others (by frequency): Between 2nd and 3rd molars Oppositely to 2nd molar Behind the 3rd molar.	GPC orientation: Antero-inferio-medial. No relevant side discrepancies in the GPF to 3rd molar, PHBP, PteH, and PMS distances.

Table 1: data extracted from the articles analysed

Article :	Study:	Results:	Results (bis):
Douglas R et al 2006	HDCT study of the GPC length for pterygopalatine injection in sinus surgeries. Comparison with other studies. Analysis: 22 American cadavers heads of normal anatomy.	Mean GPC length and mean thickness of the palatal mucosa: No relevant gender differences.	25mm of depth and 45° angle recommended for the injection.
Ikuta CRS et al 2013	CBCT anatomical study of the GPF. Comparison with other studies. Analysis: 50 Brazilians individuals of normal anatomy, 100 GPF observed. 27 men, 23 females. Age: 35.8 (mean)	GPF-maxillary molars position: majority: palatal side of the 3rd maxillary molar positions. Rare occurrence of medial or distal to the 3rd molar position. No occurrence of the medial to the 2nd molar position.	GPF size, GPF-AR, GPF-MMS measures and GPF-maxillary molars position: No relevant discrepancies between genders nor sides. CBCT is a useful material for clinical examinations.

Table 1: data extracted from the articles analysed

Article :	Study:	Analysis:	Results:
Lopes PTC et al 2011	Anatomical study of the GPF. Comparison with other studies	94 Brazilian skulls. 65 men, 29 females.	GPF-MSP and GPF-PHPB measures: No relevant side nor gender differences. GPF shape: oval (mean) Other: slit, round.

Article :	Study:	Results:	Results (bis):
Dave MR et al 2013	Anatomical study of the GPF. Comparison with other studies. Analysis: 100 Indian skulls. 60 men, 39 women, 1 undetermined.	GPF-maxillary molars position: most common: medial to 3rd molar. Others (in frequency order): Behind the 3rd molar Between 2nd and 3rd molar. Medial to the 2nd molar.	GPF-MPS, GPF-PHPB measures and GPF to maxillary molars positions: No relevant differences between sides of the same cranial types. Discrepancies were noted between different cranial types.

Table 1: data extracted from the articles analysed

Article :	Study:	Analysis:	Results:
Teixeira CS et al 2010	Anatomical study of the GPF for surgical procedures using the GPC. Comparison to other studies.	141 Brazilian skulls, 82 males, 59 females. Age: 31.64 (mean)	GPF-MPS, GPF-IF and GPF-Maxillary tuberosity distances: No relevant side differences, except in GPF-MPS measures. Genders differences noted. GPF to maxillary molars: 3rd molar prevalence.
Mustafa AG et al 2018	Palatal anatomical study for gender recognition.	300 upper casts from Jordanians subjects. Age: 6-50 years old. Adults: 150 models. 66 men, 84 women. Children: 150 models. 75 boys, 75 girls.	Males presented higher dimensions in the measurements. Differences were lower in the child group (only in width and length)

Table 1: data extracted from the articles analysed

Article :	Study:	Results:	Results (bis):
Tomaszewska I et al 2014	Use of landmarks to situate the GPF. Description of the GPF and LPF anatomy. Cross comparison with other populations. Analysis: 1200 CBCT images, 150 Polish skulls of normal anatomy. 1350 samples, 695 women, 655 men.	GPF-maxillary molars: Majority: oppositely to the 3rd molar. Similar mean result in the world population. GPF-adjacent anatomical landmarks: No relevant side differences, except for GPF-IF and GPF-MMS measures. Gender differences are noted.	LPF: from 0 to 5. Mean: 1.6 right, 1.5 left. Absence of LPF: the LPN may exit through the GPF. Multiple LPF may create a large LPF, that could be wrongly seen as the GPF.
Mellema JW et al 2004	Study: Pathways of the GPN for endoscopic surgeries.	Analysis: 6 cadavers, 11 pterygomaxillary fossae. Distance form lateral bony nasal sidewall to medial edge of the GPN. Relationship of the sphenopalatine artery to the GPN.	Results: The GPN courses forward and downward reaching the GPF. The sphenopalatine and posterior nasal arteries cross perpendicularly on the GPN. The GPC surface ranged to dehiscence to complete thin bone cover.

5. DISCUSSION:

5.1. The study of the anatomy of the Greater palatine nerve and lesser palatine nerve; Recent advancements in the research and implications for the dental practice:

Updates and research in human anatomy and physiology are an important and beneficial matter. New reviews and studies, even if conducted on previously assessed aspects of the human anatomy, are necessary in order to better understand and obtain a more profound knowledge of the human body physiology. (1–8,17–28,30–32,34–36)

The anatomical and physiological characteristics of the palatine nerves make no exceptions to this reviewing process. Continuous researches have been conducted to acquire a more precise understanding of the anatomical routes and terminations of these nerves.(4–7,36) Possessing the basic knowledge of the greater and lesser palatine nerve is essential when reviewing the potential variations existing in the human population. (1,2,4)

Endoscopic anatomical study is a reported method in the literature that allows a more direct and precise assessment of certain anatomical regions. In this regard, the GPN study has greatly benefited from this approach.(37)

Recent studies have brought to light multiple primordial findings concerning the anatomy of the greater and lesser palatine nerves.

– The GPN is crossed by the sphenopalatine and posterior nasal arteries. This fact must be taken into consideration when performing surgical treatments implying these structures to avoid possible iatrogenic effect.(16,37)

– In the same way, the lateral surface of the canal showing variable bone structure thickness is of importance when performing anesthesia techniques involving the GPC, such as the maxillary nerve block.(37)

– The role of the LPN is greater than previously thought. Its protection during cleft palate reconstructive surgeries is essential for the preservation and recovering of speech capabilities during the postoperative phase of the treatment.(9,15)

– The confirmed role of the LPN in the innervation of the levator veli palatini, the palatal mucosa, the glandular tissues, the uvula muscle and palatopharyngeus have open ways for sleep apnoea disorders treatments as well as for the neuromodulative therapies. (9,15)

– Studies on the GPN and LPN regarding their positions and possible courses show variations, like in the GPN, which may in certain individuals innervate the upper premolars and molars. This renders it sensible, in this region, to the superior alveolar nerve block.(4,6)

This information must be kept in mind too, when administering anesthetic dose for the greater palatine nerve block as well as for the maxillary nerve block, to avoid failure of anesthesia or more serious iatrogenic consequences. (2,4,5)

5.2. Anatomical variations are present in the human general population: the influence of ethnicity, sexes, and morphological anatomical facial patterns:

The anatomical landmarks and subsequent potential variabilities regarding the GPN and LPN observed in the general population in various ethnic groups, ages, sexes and morphological patterns imply that inherent risks of injuries for the patient exist at various degrees when performing certain procedures, especially surgical procedures.(5,7)

General anatomical landmarks described in early reviews did not always account for the possible variations existing in different human groups. Further reviews concerning specific populations, with the help of dissections studies on selected corpses or observations on living subjects, permit the entire dentistry profession to better understand the possible differences that may be encountered in the common practice.(5,7)

5.2.1. Anatomical variabilities encountered between genders:

GPC length: The GPC length tends to be longer in males, a result in correlation with higher palatal size and height in males, having on average bigger skulls.(8,22,36) Variations are noted considering populations: the difference between genders in GPC length is low in Lebanese population samples.(21)

GPF diameter: The GPC diameter tends to be larger in males.as in the Turkish population (23,36). Variations exist as these differences may not appear in other populations. (5,26)

GPF position to the maxillary molars: The most frequent location reported in the world population was oppositely to the 3rd molars in both genders, but positional tendencies tend to be more spread out in females.(36)

GPF and LPF position to adjacent landmarks: Males presented on average greater distances between the GPF and other anatomical landmarks used in the literature, such as the IF, PNS, PHPB, AR, PteH, LPF, opposite GPF and the middle palatal suture.(36)

LPF number: No significant gender differences were noted regarding the number of LPF between genders. (23,31,32,36)

Anatomical and physiological discrepancies between males and females can be noted in the general population in the entirety of the human body, including by extension the head and neck area. These differences encompass an extremely large variety of processes resulting in, for examples, variations in bone density, shape and size, palatine foramina and canals positions.

The observational and analytical studies realised with measurements in different populations showed gender variabilities in the position and dimension of the greater and lesser palatine canals, as well as in the location of the greater and lesser palatine foramina.

It is important to note that these observations showed that the differences could be rather minimal or more significant, both in their results and clinical implications, when considering specific parameters or populations samples.

5.2.2. Anatomical variabilities encountered when comparing the sides of the palatal bone:

- Relationship of the greater and lesser palatine foramina to the maxillary molars and other adjacent anatomical landmarks:

The majority of the samples did present a certain degree of variability regarding the position of the GPF to the maxillary molars, however the major part of the studies did not consider these results to be significant enough for them to be considered clinically relevant, a fact notably shown in Brazilian (7,31,32,34,36), Indian (5,17,18,25,27,28,32,33,36), Caucasians (29,36), and Nigerians subjects. (36)

- GPC characteristics:

Lebanese population: Sides differences were minimal when considering the GPF diameter and the GPC length. However, it must be noted that the presence, place and magnitude of the GPC curvature could vary, the left side tending to be flatter than the right side. (21)

Iranian population: Differences were noted regarding the length of the GPC from side to side, especially in males. (22)

North American population: Some samples presented variations (especially in males) in the GPC pathway. (8,30)

Caucasian European, North Americans, Lebanese (regarding length), Brazilians populations: Research did not find important differences in the dimension of the GPC from side to side. (7,21,31,32,34,36)

The literature reported some observation of variabilities in the anatomy from sides to sides when comparing the GPC length, in multiple populations.
The latter may possess an influence in terms of anatomical variations encountered, since certain samples on different populations did not possess such variabilities. It must also be noted that intra-population variabilities were also shown regarding the presence or not of such discrepancies.

- LPF characteristics and number:

Turkish population: Differences in number of LPF was not considered statistically significant regarding palatal sides. (23)

Indian population: Differences were more significant. Observations in individuals with one LPF showed that these single foramina were usually present on the right side of the palate whereas in individuals with two LPF, studies show that these pairs were usually more present on the left side of the palate. (5,17,18,25,27,28,32,33,36)

The number and anatomical characteristics of the lesser palatine foramina can vary when comparing the sides of the palatal bone.(5,17,18,25,27,28,32,33,36)
The shape of the foramina tends to be similar when comparing both sides of the hard palate. (5,17,18,25,27,28,32,33,36)

Side by side comparison is a valid question to assess when comparing the greater and lesser palatine nerves anatomy and the position of the GPF and LPN.
While perfect symmetry cannot be expected when studying the human anatomy, statistical systemic asymmetry must be considered. (1)

As seen previously on the observed populations, the differences could be considered significant or not, showing again a potential influence of the geographical or ethnical background of the samples' individuals.

It is interesting to note that absence of LPF, a condition encountered in certain samples, may lead to a case where the LPN goes through the GPC alongside the GPN, potentially leading to an unwanted anesthesia of the former when performing GPN numbing.

The relevancy regarding the variations of the number of LPF encountered from one side to another of the palate is still debated. It may also be linked to an increased risk of accidental LPN anesthesia during GPN or GPC usage anesthesia procedure.

5.2.3. Anatomical variabilities between and inside population groups:

Variabilities in the greater and lesser palatine nerves observed in different ethnicities or population groups are very important to consider.
Several accidental situations may arise that could lead to failure of treatments, or even put the patient in danger of an iatrogenic injuries, such as when applying anaesthetic solutions or proceeding to a surgical treatment. (2,4)

These variabilities are various in nature and depend, similarly as in gender comparison, on the specifically studied populations samples and from the considered parameters.

- Position of the GPF to the 3rd maxillary molars:

Worldwide: On average, the most frequently recorded position of the GPF was oppositely to the 3rd maxillary molar.(36)

Caucasian populations: The 2nd maxillary molar was the second most frequent position, except in Romanian samples, which was that of between the 2nd and 3rd maxillary molars.(29,36)

Turkish populations: The most frequent position encountered in the Turkish population sample was medial to the 3rd molar. (23)

African populations:

South Africans: marked presence of the GPF distally to the 3rd maxillary molars, when compared to other African groups. (36)

Nigerians: frequent positioning of the GPF on both the positions of medial to the 3rd molars and between the 2nd and 3rd molars is observed, but recent studies found it closer to the position of oppositely to the 3rd molar. (36)

East Asian populations: *Thai and Chinese:* great inter populations variabilities; from oppositely to the 2nd maxillary molar, to between the 2nd and 3rd molar, and oppositely to the 3rd molar. (19,36)

Brazilian populations:

Prevalent presence of the GPF distally to the 3rd molar. (7,31,32,34,36)

North American populations:

The most common location of the GPF was that of between the 2nd and 3rd maxillary. However, due to the small sample, careful consideration must be given. (36)

Indian populations:

The most frequent position recorded was oppositely to the 3rd maxillary molars. Significant variety in the data appears when comparing the different studies realised. (5,17,18,25,27,28,32,33,36)

- GPF position to adjacent anatomical landmarks (using GPF distance to MMS and to PBHP as illustrative references):

Caucasian populations: The GPF-MMS value varies from 15.9 mm in the Polish population (36) to 14.5 in the Romanian group. (29)

The GPF-PBHP value also differ, from 4.8 mm in the Polish group (36) to 4.4 mm in the Romanian one.(29,36)

African populations: Two Nigerian study groups presented different values of distance between the GPF-PBHP value, one presenting an average value of 5 to 5.1mm, the other 3.5mm. The GPF-MMS measures were more homogeneous. (36)

East Asians populations: the GPF-MMS distance in the Thai population was on average 14.7mm, in contrast to the one recorded in the Korean population, at 16.2 mm. (36)

Brazilian population: Intra population differences can be noted in the GPF-MMS values between studies. (7,31,32,34,36)

Indian populations: Indian studies globally followed the same trend regarding intra population variations in the GPF-MMS values. (5,17,18,25,27,28,32,33,36)

- Dimension and form of the GPF:

The comparative analysis of the dimension of the GPF itself indicate differences between populations. Overall, the GPF tends to possess greater dimension antero-posteriorly than latero-medially, and present an oval shape. (28,29,32,36)

- GPC length:

North American population: Intra population variabilities are noted. The lowest average recorded GPC length in the present literature was 18.5mm, while other studies reported an average GPC length of 27mm in women and 28mm in men, with a 23 to 33mm range. (8,30)
Middle eastern populations: Variation in the same world region is shown, between the Lebanese and Iranians populations: the average GPC length recorded in a Lebanese population sample is 35.02mm (21), and of 31.82mm in an Iranian population sample. (22)

- GPC course:

Caucasians (Romanians), African, Indian and Chinese population samples:

In the Romanian population, the most frequent direction of the canal was antero-inferio-medially, in 82% of the sample subjects. (29)

In the Chinese population, this number tended to be closer to 90.5%, but only reached 62.4% in Indian individuals, 60% in previously conducted studies in Caucasians and 58.5% in Nigerians samples. (29)

- LPF characteristics and number:

Indian population: Indian studies show variations in LPF numbers: One study found an average number of 1.39 on the right side, and 1.43 on the left side, (5) while another found higher values, at 1.8 on the right side and 1.9 on the left side.
The maximum reported LPF number could also vary, from 3 to 6. (5,17,18,25,27,28,32,33,36)

Caucasian (Greek) population: the maximum LPF number recorded was also 5. The most common number of LPF per side found was of 1. (26)

African (Kenyan) population: the most common LPF value was 1. The maximum number was again 5. (36) Occurrences of more than one LPF per side was more frequent in this population than that of the Greek samples. (26,36)

Caucasian population: Studies realized European individuals found that the most common LPF number encountered per side on average was 2. (36)
Turkish population: Studies realized in the Turkish population reported an average LPF number from 2 to 3 per side as well, with a maximum number of 5. (23)

Variabilities can be observed in different but also similar ethnicities groups and populations, in the GPF, GPC and LPF anatomical characteristics (in terms of position, sizes and direction). (5,7)
These parameters are very important to consider, as several situations may appear that could lead to failure of treatments, or even put the patient in danger of an iatrogenic injury, such as when applying anaesthetic solutions or proceeding to a surgical treatment. (2,5,7)

A dentist working abroad in a different population should keep in mind these potential anatomical variabilities. Similarly, when treating a patient of a specific minority ethnicity in certain countries, the dental professionals must bear in mind that the anatomy might differ. (5,7)

It must be underlined that the exact origin of populations-based variabilities is still a matter of debate. Ethnic differences can be thought as the main reason, but we could also turn our attention on the method of measurement discrepancies between the different examiner teams. (5,36)

In any case, the results are not homogeneous, and reinforce the need of performing careful pre-clinical examinations on every patient before performing any treatment involving the GPN, and the GPF as a landmark, as a complement of the use of a theoretical anatomical landmark. (5,7)

5.2.4. Anatomical variabilities encountered between facial morphological patterns:

The human facial anatomy and morphological types present in the human population influence the palatine bone anatomy, including on the proper location of the GPF.
This fact is noted when observing analyses of the position of the greater palatine foramen to the maxillary molars teeth, and comparing those data between the different morphological patterns found in the human population. (20)`

Indeed, the variabilities of the position of the foramen appeared to be marked when comparing the three human facial morphological patterns; Dolichofacial, Mesiofacial, and Brachyfacial.(20)

On the other hand, when analysing the shape of the GPF itself, no significant variabilities were noted during the comparative observation. (20)

Interventions implying the GPC, GPF and GPN should take into consideration the facial morphological type of the patients, especially in dolichofacial and brachyfacial cases, as the position of the greater palatine foramen and canal are subject to changes. If not considered beforehand, mistakes in anaesthetic and surgical procedures are possible.(20)

5.2.5. Anatomical variabilities encountered in the branching pattern of the greater palatine nerve:

Variations are present regarding both the branching patterns and the number of trunks that the greater palatine nerve may show. (4) Dissection studies observing this phenomenon reported a variety of patterns possessing high relevancy.(4)
The greater palatine nerve can present 5 patterns of branching (4):

- As a single trunk
- As two distinct trunks dividing themselves in two branches
- As two distinct trunks, a thick lateral one and a thinner medial one
- As three trunks emerging from the greater palatine foramen
- As four trunks emerging from the greater palatine foramen

These branching variations are to be taken into considerations before anaesthetic and/or surgical procedures. (4)

5.2.6. Anatomical variabilities encountered due to age:

Studies realized in different populations showed differences regarding the relevancy of anatomical differences linked to age, as seen between Jordanian sample studies where anatomical based gender difference were lower in children, whereases age was not considered a relevant factor in the Iranian studies. (22,35)

5.3. Multiple dentistry techniques are sensitive to the anatomy of the greater and lesser palatine nerves anatomy. Methods to improve the patients' anatomy study exist and should be considered.

Techniques and specific materials are available to accurately pinpoint the position of the LPN and GPN:

Studies realised with the objective of observing and registering the GPN and LPN used x-ray techniques, more specifically the CBCT. (3,4,8,20,22,23,31)
This specific x ray technique is used in order to achieve a more accurate imagery of the anatomical characteristics of the nerve pathways and potential terminations, notably by thoroughly study the position, orientation, tissular and osseous components of the GPC. (3,4,8,20,22,23,31)

This X-ray technique allows us to also study with accuracy the surrounding osseous structures of the palate and alveolar processes. This allows in turn to place in spatial perspective the canal and foramina with the palatine anatomical boundaries, as well as with the neighbouring teeth and their respective alveolar processes. (8,20,22,23,31)

Having the opportunity through the CBCT technique to obtain a correct 3D image of the palate is an effective, minimally invasive and safe way to improve the prognostic of the treatments involving the GPN and LPN as well as the greater palatine canal and foramina. (3,4,8,20,22,23,31)

This particular x ray technology is a substantial improvement over the classically used 2D imaging x ray, permitting a more effective spatial visualisation of the chosen anatomical area. (3,4,8,20,22,23,31)

6. CONCLUSION:

The thorough study of human anatomy is one of the pillars of modern medicine, and is the foundation for the development and the subsequent improvement of specific treatments and techniques.

In dentistry, the palatal nerves such as the GPN and LPN play key roles in the common practice surgery and implantology, but also regarding the field of maxilla-facial surgery.

A large number of studies have been conducted in order to determine and verify the anatomical landmarks in the general population, the objective being to access an ever more precise knowledge about the anatomy and the course of the GPN and LPN. Additionally, crucial information about the shape and length of the GPC, the form, position and orientation of the GPF as well as the characteristics of the LPF in terms of number and positioning have been collected.

These studies, when compared, reveal that variabilities in the human anatomy implying in this case the GPN and LPN nerve alongside their associated structures do in fact exist. These variations are not limited to a single aspect but cover in fact several variabilities and factors, including the individual gender, the studied side, the person observed facial pattern and the age.

But the observed discrepancies in the human anatomy are also observable when comparing human ethnicities and geographical groups of populations.

Indeed, the international nature of these observational and analytical studies showed that the anatomical characteristics and measurements of the GPN and LPN with their surrounding structures can be different when comparing individuals originating from different geographical and ethnic backgrounds.

The development of improved radiological techniques and materials is of great help and effectiveness when performing both common dental interventions as well as when conducting anatomical studies.

The consequences of the confirmation of the existence of variabilities in the GPN and LPN anatomy, coupled with the recent development of new and more effective imagery systems and methods presents to the dental profession both a challenge and a solution. It stresses the absolute necessity to perform a complete review of each and individual patient before starting any treatments involving the greater and lesser palatine nerves.

This systematic methodological approach can permit us to perform the most effective and safe treatment procedures for all of our potential future patients.

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