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Hypothesis

Hypotheses of Pre-Maxilla Innervations in Cleft Lip and Palate Patients

Castro CHBC^{1,2,5}, Almeida VL², Reher P³, Souza LN⁴, De Moraes M⁵, Souza ACRA⁶

¹Department of Oral and Maxillofacial Surgery, PUC Minas, Belo Horizonte, Brazil

²School of Dentistry, FEAD, Belo Horizonte, Brazil

³School of Dentistry and Oral Health, Griffith University, Gold Coast, Australia

⁴Department of Oral Surgery and Pathology, School of Dentistry, Universidade Federal de Minas Gerais, BH, MG, Brazil

⁵Division of Oral and Maxillofacial Surgery, State University of Campinas, Brazil

⁶Head and Neck Anatomy and Orthodontics, Dentistry School, Centro Universitário Newton Paiva, Belo Horizonte, Brazil

*Corresponding author: Dr. Leandro Napier de Souza, Universidade Federal de Minas Gerais, Faculdade de Odontologia, Departamento de Clínica, Patologia e Cirurgia Odontológicas. Av. Antônio Carlos, 6627 - Campus da Pampulha, Pampulha, 31270-901 - Belo Horizonte, MG - Brazil, Tel: +55 31 3409-2414; Email: leandronapierdesouza@gmail.com

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Introduction

Cleft lip and palate (CLP) are birth defects that affect the midface, usually compromising aesthetics and several orofacial functions. Management of these cases implies the need of a multidisciplinary team, laying the foundations of a comprehensive rehabilitation [1]. Cleft lip and palate may be associated to some syndromes, most commonly the Van der Woude Syndrome [2].

Cleft can be classified into three groups according to Spina (1973) [3], taking into account the anatomical position of the nasopalatine canal/foramen:

- Pre-foramen cleft – affects only the lip, with or without involvement of the alveolar ridge and nose.
- Trans-foramen cleft - affect the lip, alveolar ridge and the palate.
- Post-foramen cleft - affect only the palate (soft and/or hard).

Clefts can be unilateral, bilateral or medians.

Formation of pre-maxilla

On the 24th day of intrauterine life the first gill arch is the

maxillary process, so the estomodeo (primitive mouth) is limited by the cranial frontal prominence, the maxillary process laterally and ventrally by the mandibular process. By the 28th day, localized thickenings develop in the ectoderm of the rostral frontal prominence, resulting in a horseshoe-shaped depression, the nasal pit. The thickening laterally to the pit is the lateral nasal process, and medially to it, the medial nasal process. Between the two nasal processes there is a new area called the frontonasal process. The medial nasal processes of both sides and the frontonasal process join to form the middle portion of the nose, the middle portion of the upper lip, the anterior maxillary and primary palate. Between the seventh and eighth weeks of intrauterine life, the secondary palate is formed from the forming maxillary processes, thus separating the oral and nasal cavities. The frontonasal process and the medial nasal processes increase the number of cells to, together, form the four incisors and the pre-maxilla region [4].

Fissures happen when there is a fault on the union of any of these processes, which is considered a failure of formation. A fault at the junction of the frontonasal and medial nasal processes results in a cleft lip (pre-foramen cleft). A fault at the junction of the right and left maxillary processes results in a

cleft palate (post-foramen cleft). If both faults occur, there is a complete cleft lip and palate fissure (trans-foramen cleft) [5].
Innervations of the maxilla

The maxilla is innervated by the maxillary nerve, which is a branch of the Trigeminal nerve, the fifth pair of cranial nerves. The maxillary nerve leaves the cranium through the foramen rotundum and soon reaches the top of the pterygopalatine fossa. The pterygopalatine nerve is a descending branch of the maxillary nerve that passes through the pterygopalatine ganglion (without maintain functional relationships with it). From the ganglion a medial branch derives, the sphenopalatine nerve, which penetrates into the nasal cavity through the sphenopalatine foramen [6-9]. In the nasal cavity, it emits the posterior nasal nerves and the sphenopalatine nerve. The posterior nasal nerves innervate the posterior and superior area of the nasal cavity. The nasopalatine nerve (NPN) runs from the roof of the nasal cavity to the incisive canal, under the mucosa of the nasal septum, reaching the anterior hard palate. The NPN innervates the mucosa of the anterior palate between canine and central incisor, and the mucosa of the anterior nasal septum [6-9].

The descending palatine nerve leaves the pterygopalatine ganglion inferiorly, and enters the greater palatine canal. In the canal it divides into two branches, the greater and the lesser palatine nerves [6-9]. The greater palatine nerve (GPN) leaves the canal via the greater palatine foramen, reaching the hard palate. Here it usually divides into at least two branches, which run forward, marking the surface of the palate, as it is accompanied by a vascular bundle. The greater palatine nerve provides sensory innervation to the mucosa of the hard palate up to the canine region. The greater palatine nerve also innervates the palatal gingiva of the maxillary posterior teeth. The lesser palatine nerve leaves the canal via the greater or lesser palatine foramen, and innervates the glands and mucosa of the soft palate [6-9].

After passing through the pterygopalatine fossa, the maxillary nerve sends another branch, the posterior superior alveolar nerve (NASP). This has a downward path through the posterior wall of the maxilla, where the nerve enters this wall via the alveolar foramina. Through intraosseous canaliculi, the nerve reaches the maxillary molars, except the mesiobuccal root of the 1st molar. It also innervates the buccal hard and soft tissues adjacent to the molars, and the mucosa of the maxillary sinus [6-9].

The infra orbital nerve (ION) is the anatomical continuation of the maxillary nerve, which is renamed when it crosses the inferior orbital fissure to reach the orbit. On the floor of the orbit, the ION passes through the infraorbital groove followed by the infraorbital channel, leaving the orbit via the Infraorbital (IO)

foramen. While in the orbit the nerve has two branches, the middle superior alveolar nerve (MSAN) and anterior superior alveolar (ASAN). The NASM, present in about 70% of individuals, innervates the pulp and periodontium of the premolars and eventually the mesiobuccal root of the maxillary first molar. It also contributes to innervate the mucosa of the maxillary sinus in the region corresponding to the zygomatic process of the maxilla [6-9]. The ASAN, leaves the ION about 1 cm before the IO foramen, and follows a intraosseous path through the anterior wall of the maxilla, innervating the maxillary sinus mucosa and the pulp (dental branches), interdental papilla, periodontal and adjacent alveolar bone of the upper incisors and canine (periodontal branches). Finally the ION leaves the canal via the IO foramen, splitting into several branches in the face, the lateral nasal branch, the upper lip branch and the inferior palpebral branch, providing sensory innervation to the lateral side of the nose, upper lip and lower eyelid respectively [6-9].

Innervation of the pre-maxilla in patients with cleft

Bohn (1963) [10] was the first author describing the possible innervation of pre-maxilla in the cleft jaw. This paper stated that bilateral bundles of NPN descend along the vomer, on both sides, and reach the pre-maxilla and, from there, converge to form the median nerve. The median nerve, in its turn, runs through the cleft innervating the soft tissue in the cleft area. A major nerve branch of NPN is responsible for innervation of palatal mucosa, as well as the anterior teeth and the buccal mucosa, through penetration of the pre-maxilla.

The region of the pre-maxilla in patients with CLP has clear sensory innervation, since teeth, hard and soft tissues adjacent to the cleft require anesthesia for invasive procedures [11].

Therefore, as the area has sensory innervation, the questions to be answered are: (1) which nerves supply the pre-maxilla; and (2) which anatomical pathway do these nerves travel to reach it. Answers to these questions will be useful when planning surgeries to repair the cleft, ensuring that the innervation of the area will be preserved.

As shown, the anatomy of the maxillary nerve is well described, but papers discussing the subject of innervation of CLP are scarcely available in the literature. The objective of this study is to discuss the possible mechanisms of innervation of the pre-maxilla of patients with cleft lip and palate, since the presence of the cleft modifies the neuroanatomy of the region.

Discussion

Possible nerve supplies of the pre-maxilla

Three nerves could innervate the pre-maxilla: (1) greater pal-

atine nerve; (2) nasopalatine nerve; and (3) infraorbital nerve.

- Greater palatine nerve - responsible for the innervations of the posterior hard palate. This nerve could develop more anteriorly, reaching the anterior hard palate, between the central incisor and canine, since the nasopalatine nerve was prevented from reaching this area, and just innervating the anterior palate between cleft or cleft sides (Figure 1B);
- Nasopalatine nerve (NPN) - this nerve runs down the nasal septum to pass through the incisive foramen, and apart from innervating the palatal side of the pre-maxilla, it may supply its buccal side, between the cleft or cleft sides (Figure 1A);
- Infraorbital nerve - it will innervate the nostrils, and could develop more, innervating the buccal side of the pre-maxilla, since the infra orbital branch, anterior superior alveolar (ASA), was prevented from reaching the fissure (Figure 1A).

The first hypothesis is implausible, since the cleft palate stops exactly at the point where the nasopalatine starts its territory of innervation, between upper canine and lateral incisor, preventing the greater palatine nerve from reaching the anterior region of the palate (Figure 1B). After palatoplasty surgeries and bone grafting there is a small possibility that the greater palatine nerve could develop anteriorly, being more likely involved in the re-innervation of the palatal side of the pre-maxilla. Besides that, this possibility is not supported by the available literature.

The second hypothesis is plausible, because the buccal region and anterior teeth have sensitivity [11]. As the NPN goes down the septum, it would develop another branch before passing through the incisive foramen, resulting in two branches: the regular one, that passes through the foramen, will supply the palatal aspect of the pre-maxilla and the other branch would

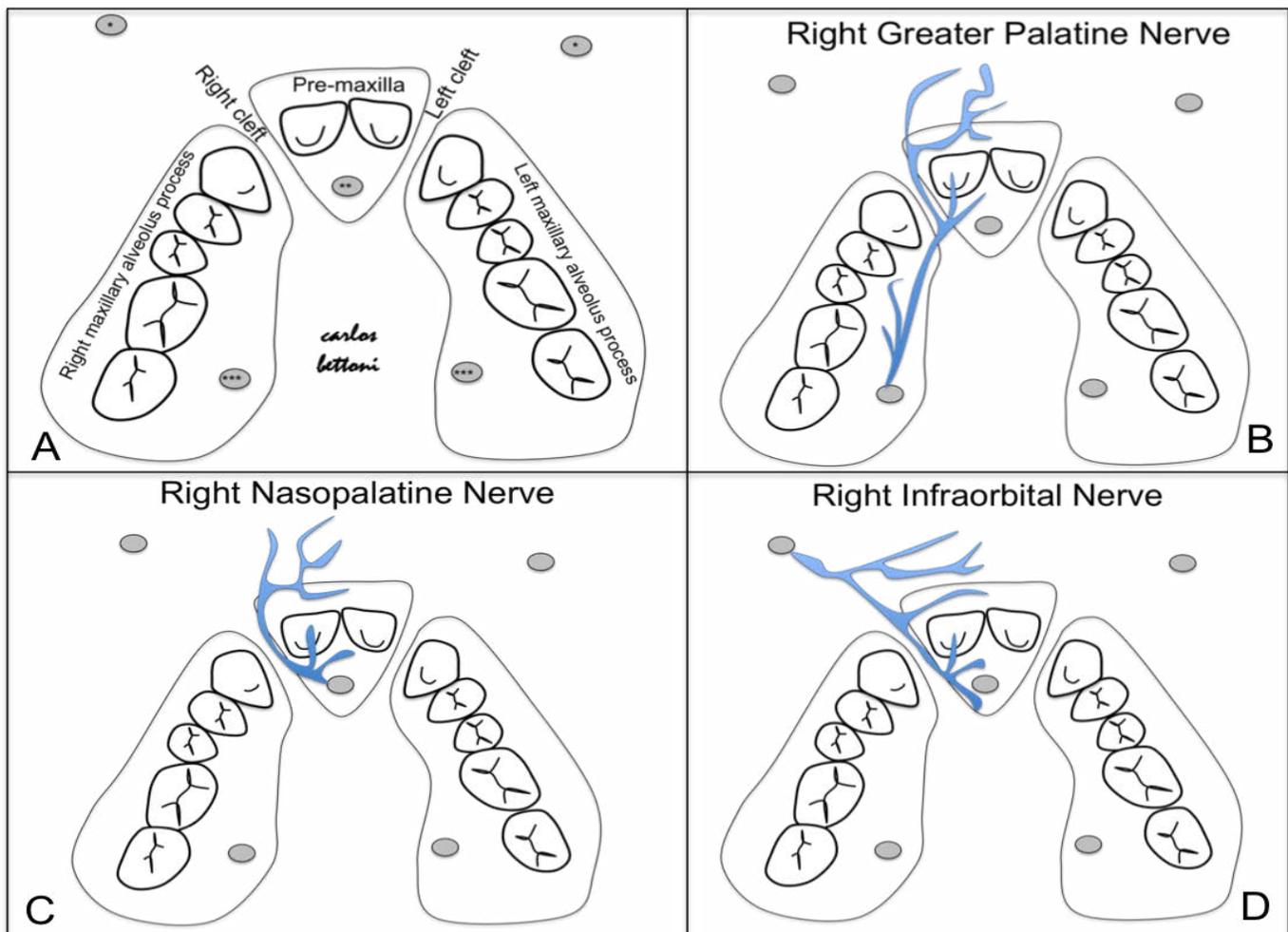


Figure 1. A. Occlusal view of the maxilla in bilateral CLP showing the pre-maxilla, clefts and maxillary alveolar processes (infra-orbital foramen*, incisive foramen**, greater palatine foramen***). B. Right greater palatine nerve supplies maxillary alveolar process (palatal aspect), pre-maxilla (teeth, buccal and palatal aspect). C. Right nasopalatine nerve supplies pre-maxilla (teeth, buccal and palatal aspect) D. Right infra-orbital nerve supplies pre-maxilla (teeth, buccal and palatal aspect).

leave the septum before entering the incisive foramen, and turns buccally to innervate the buccal side and the teeth of the pre-maxilla (Figure 1C). The surgical correction of CLP would not disrupt the path of the NPN branch since these surgeries are not done at this specific location (region of the nasal septum and between the incisors). In the event of the neo-innervation, the region will not suffer and may only be innervated by two nerves, the nasopalatine and the anterior superior alveolar. So, this possibility could be supported in part by the proposed by Bohn (1963) [10]. Furthermore, Meyer and colleagues (2007) [12] have shown that the region of central incisors may also receive innervations from the NPN in patients without CLP, providing support for this hypothesis.

The third hypothesis is also plausible, but less likely to happen. The infraorbital nerve has two branches that could contribute to the innervation of the pre-maxilla, one before the IO foramen, the anterior superior alveolar nerve (ASAN), and the lateral nasal branch, that innervates the lateral side and wing of the nose, after the nerve reaches the face via the IO foramen. If the ASAN is prevented from reaching the anterior region of the cleft, then the lateral nasal branch could develop more and travel inferiorly through the nose reaching the pre-maxilla (Figure 1D). There is no anatomical structure that prevents this hypothesis from happening, although this pathway is more complex than the others, because the branch may be intraosseous. In one hand, considering that nerve and blood supply follow the same distribution in normal situations, the findings of some studies regarding the blood supply in CLP could support in part this hypothesis [13,14]. In other hand, the likelihood of vascular adaptation is more prone to occur than its nerve counterpart.

The surgical correction of CLP will also not interrupt this path, since it is well above the surgical site. In the event of neo-innervation this would happen similarly to the second scenario, with the region being innervated by two different branches, requiring anesthesia for invasive procedures.

Conclusion

No final conclusion can be drawn in relation to the innervation of the pre-maxilla in CLP cases; hence only hypotheses have been formulated. The most likely hypothesis would be the third one (IO nerve), however it presents a more complex anatomical pathway. The second hypothesis, where the nasopalatine nerve would supply the entire pre-maxilla, not only the palatal aspect, presents a simpler and easier pathway. The most likely scenario would be a combination of the second to the third hypothesis, whereby the nasopalatine would innervate the palatal side and the infra orbital nerves would innervate the teeth and the buccal side of the pre-maxilla. Further CLP anatomical studies, in specialized centers, are necessary to confirm or invalidate these assumptions.

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