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as avoiding surgical sutures. The surgical design and technique also minimised post-operative discomfort and complications resulting in stable healing overtime, making the procedure fully accepted by children.

Keywords Children oral surgery; Er:YAG laser; Labial frenectomy; Wound healing.

Laser labial frenectomy: a simplified and predictable technique. Retrospective clinical study

ABSTRACT

Aim Anomalous maxillary median labial frenum may be associated with undesired effects such as persistence of diastema between anterior teeth or traction of marginal gingiva. The aim of this study was to propose a surgical frenum repositioning technique that is minimally invasive, safe, easy, reproducible, and predictable. Another objective of the study was to identify clinical scenarios that could have indication for labial frenectomy associated with early orthodontic therapy, so as to justify early frenum repositioning in children. A retrospective assessment of clinical outcomes of this technique is described.

Methods A total of 20 frenectomies were performed on children aged 8 to 10 years. Frenectomies were performed with Er:YAG laser set at 150mJ 2.25-3.0W and 15-20 pulse per second, with water spray. Recall visits were done at 7, 21 and 90 days and 1, 2, 3 and 4 years.

Results At post-operative visits, all patients reported no post-operative pain or minimal discomfort. None experienced post-operative bleeding at a distance of few hours. All patients reported that the procedure was well tolerated and "acceptable". No recurrences occurred 4 years after frenectomy.

Conclusion The Er:YAG laser used in this study allowed considerable reduction of the operating time, reducing the amount of local anaesthetic used as well

Introduction

Labial frenum is a fold of fibro-mucous tissue that attaches lips and cheeks to the alveolar mucosa and/or gingiva and to the underlying periosteum of maxillary and mandibular bone. It is made of connective tissue and elastic and collagen fibers; muscular fibers originating from the orbicularis and fat tissue can be also present. Vascular structures and thin peripheral nervous ramifications are barely present. Placek et al. [1974] classified the labial maxillary median frenum based on its anatomical site of insertion: mucosal insertion, gingival insertion, papillary insertion and penetrating insertion (Table 1). The correct position of insertion of labial frenum is on the mucogingival junction without interference with the adhesion of the attached gingiva [Henry et al., 1976]. In particular clinical conditions associated to thin gingival biotype, lack of adherent gingiva, and/or with no evident limits of the mucogingival junction, the maxillary median labial frenum can insert in an anomalous position, between the central incisors, in a progressively coronal position, also deeply in the bone with an insertion which is potentially harmful [Olivi et al., 2010] (Fig. 1). Beside its point of insertion, labial frenum can be also defined as abnormal when its structure is hypertrophic, fibrotic-stiff, ample and fan-shape like or bifid-ending [Olivi et al., 2010]. The presence of an abnormal or anomalous frenum on thin gingival biotype can induce, through ischemic phenomena resulting from traction, a progressive buccal recession of the gingival margin known as "pull syndrome" [Bergstrom

Normal Anatomy

Class I	Mucosal insertion at the mucogingival junction
Class II	Gingival insertion below the mucogingival junction and above the gingival margin of the central incisors

Anomalous Anatomy

Class III	Papillary insertion, buccally between teeth
Class IV	Papillary insertion at palatal papillae

TABLE 1 Anatomical classification of frenum insertion modified from Placek et al., 1974 and Kotlow, 2004.



FIG. 1A female Patient aged 9 years with Angle Class 2 Division 1 malocclusion. The pre-operative image shows presence of thin gingival biotype, lack of adherent gingiva, and no evident limits of the mucogingival junction (blue arrows). The labial frenum is inserted at papillary and palatal level in an anomalous position (Class III and IV) (blue dots).

et al., 1973]. An anomalous insertion can also interfere with adequate oral hygiene causing marginal gingivitis in the surrounding areas and contribute to the onset of carious lesions. Furthermore, the pathological insertion of the frenum can contribute to breastfeeding difficulties in infants [Kotlow, 2004; Kotlow, 2011] and in these cases early intervention has been proposed. If a pathological frenum is not promptly diagnosed, it could at times cause developmental anomalies of anterior region of the maxilla which can manifest during youth [Koch and Polsen, 2001; Huang and Creath, 1995].

The upper labial frenum is capable of maintaining a diastema, but its role in the aetiology of an anterior diastema or in its reopening after orthodontic treatment is controversial. In the past, authors described how during the stage of physiological eruption, the anterior diastema would spontaneously close, therefore suggesting that the closing of the diastema was not influenced by frenectomy [Taylor, 1939; Bergstrom et al., 1973]. On the contrary, it was reported that hypertrophic, stiff, fibrotic or fan-like shaped frenum could hinder the closing of the diastema thus advising its removal or repositioning [Edwards, 1977]. More recently there has been a tendency to justify the removal of a labial frenum in case of persistence of central diastema after the permanent canines have erupted. However, possible harmful clinical scenarios associated with pathological frenum, for which surgical intervention may be indicated, have been described [Olivi et al., 2006; Olivi et al., 2010] (Table 2).

When surgical removal of the labial frenum is recommended, various surgical techniques are available: frenectomy with Z-plasty and frenotomy with V-shaped incision [Edwards, 1977]. Alternative techniques such as electro- or radiosurgery were progressively replaced in past years by laser surgery [Genovese and Olivi, 2010].

The purpose of this study is to clarify the diagnosis

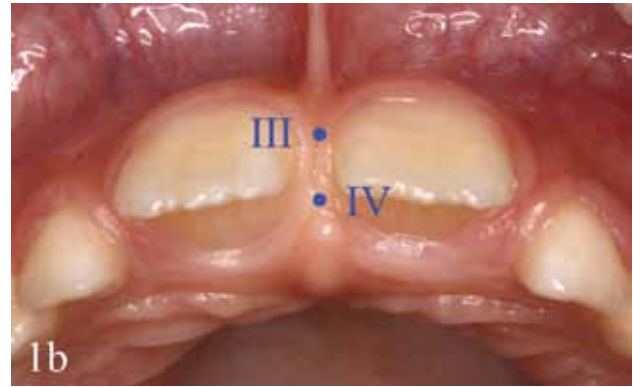


FIG. 1B Palatal view shows ischemic area in median area due to pulling from frenum and lips. The blue dots show the insertion of the frenum in the interpapillary area and palatal site (Class III and IV).

of frenum anomaly and/or abnormality and to identify orthodontic clinical scenarios that could have indication for early labial frenectomy, also evaluating patient's gender, his/her individual psychological maturity, the type of orthodontic therapy chosen, specifically, interceptive, functional or fixed multiband orthodontics. This study also aims to propose a laser surgical technique that is minimally invasive, safe, easy, reproducible, and predictable, being performed with a standardised surgical design that minimises post-operative discomfort and complications and that leads to stable results over time, so as to justify early intervention in children. A retrospective assessment of clinical outcomes of this technique is reported.

Methods

Upper labial frenectomies were performed over four years (from 2011 to 2015) on 20 children whose age ranged between 8 to 10 years. Early indication for surgery was presence of anomalous and/or abnormal labial frenum inserted at palatal papilla (Class IV), associated with presence of diastema between central incisors, in patients needing orthodontic therapy. The treatments were performed by two experienced clinicians using the same laser, setting and surgical protocol. Following an explanation of the clinical treatment plan and alternatives, the patient's parents signed an informed consent.

Laser setting

Frenectomies were performed using an Er:YAG laser (2940nm, LightWalker AT Fotona; Ljubljana, SLO) with sapphire conical tip (diameter of 600 microns). Local anaesthesia was always used infiltrating 0.3 ml local anaesthetic (4% articaine with vasoconstrictor 1:200.000) at buccal and palatal site of insertion of the frenum. Energy output of 150 mJ was used at a repetition frequency ranging from 15 pps to 20 pps (average power

of 2.25-3.0 Watts respectively). Pulse duration of 300 microseconds was used for soft tissue vaporisation and of 100 microseconds for periosteum incision. The air/water spray was set to 4/5 of the panel emission scale corresponding to a water flow of 25 ml/min.

Surgical Protocol

The operative modality was in "focused" mode, with the tip in close contact to the target tissue: in touch with frenum, not in-touch on the periosteum. The lip was lifted with hands by the operator to stretch and expose the frenum. Four main consecutive steps were performed.

Step 1: The first incision is performed vertically along the axis of the frenum while stretching the frenum itself that in few seconds opens in a rhomboidal shape wound; incision 1 starts buccally at papillary level, extending up few millimeters (5-10 mm) above the muco-gingival junction, as ideal point of insertion of a frenum (Class I), and down toward the palatal papilla, the actual site of its insertion.

Step 2: The second incision then follows with a V-shape design, gentle incising the periosteum along the mucogingival junction without extending distally beyond the median axis of central incisors, on both sides. A couple of passages from one side to the other allows marking of the mucogingival junction, designing the formation of a thin connective scar on the junction, as the new point of attachment of the frenum (Class I).

Step 3: The vaporisation of the remaining collagen fibers is performed horizontally to dislocate the connective fibers from the periosteum in the opened surgical area.

Step 4: The last incision vaporizes the connective fibers at palatal site of the papilla between central incisors, that are the main obstacle to the closure of diastema, connecting to the incision 1 and completing the procedure. The complete and standardised surgery lasted approximately 7-8 minutes (Fig. 2a, 2b).

Upon completion of the surgery, management of the hemostatic process was achieved with 10 minutes of compression with sterile wet gauze on the area; no sutures were applied. Furthermore, the Wong-Baker Faces Pain Scale was administered after the operation to all patients to assess their level of acceptance during laser surgery and also in the first week after surgery. Post-operative instructions were provided to each patient and to the parents. The patient was later checked again and dismissed. Administration of anti-inflammatory analgesics was never necessary. During the first week post-surgery patients were instructed not to brush the treated area, but to only self-apply a 1% chlorhexidine gel on the treated area at the end of the oral hygiene procedure. Follow-up visits were conducted at 7, 21, 90 days and 6 months after intervention to check soft tissue appearance, presence/closure of diastema, adverse events including functional complications, and any symptoms reported by the patients or by the parents (Fig. 2c). The patients were followed-up to 1, 2, 3 and 4 years (Fig. 3).



FIG. 2A Er:YAG laser frenectomy: the vertical incision 1 extends up a few millimeters above the muco-gingival junction, as ideal point of frenum insertion (Class I: blue dot), and down toward the palatal papilla, the actual site of its insertion. Incision 2 gently incises the periosteum along the mucogingival junction and does not extend distally beyond the median axis of central incisors, on both sides.



FIG. 2B One week follow-up image shows the wound healing for second intention covered by stable fibrin clot that will guide the gingival growth. After only one week the diastema is reduced for the spontaneous mesial migration of the incisors after frenum removal.



FIG. 2C Three weeks follow-up image shows evident, spontaneous, and progressive closure of diastema before any orthodontic appliance was used. The frenum is repositioned in normal position above a new defined mucogingival junction (Class I: blue dot).



FIG. 3A One year post-operative image shows the progressive eruption of lateral incisors and stable position of the frenum above the mucogingival junction.



FIG. 1B Four years post-operative image shows a light scar line delining the new mucogingival junction. After complete eruption of front teeth the frenum is permanently inserted above the junction as a Class I frenum.

Results

At post-operative visits, all patients reported no post-operative pain or minimal discomfort. None experienced post-operative bleeding at a distance of few hours. The wound healing process occurred by secondary intention by formation of fibrin clot and showed no tension on the margins and improved adherent gingiva formation in the surgical area. Presence of a thin line of scar tissue appeared progressively after three weeks, as expected, on the muco-gingival junction forming the new point of insertion of the frenum (Class I), without affecting the smile line. All patients reported that the procedure was well tolerated and “acceptable”. No recurrences were found 3 and 4 years after frenectomy.

Discussion

This study focused on several aspects of labial frenectomy: indications, timing of intervention, laser technique, including the wavelength chosen and the surgical design.

Labial frenectomy is often considered an over-treatment when the intervention is performed in mixed dentition. At age of 8-10 years, midline diastema is a physiological condition. However, when it is associated with anatomical anomalies and abnormalities of labial frenum, it is important to predict the probability of its persistence after the eruption of permanent canines is completed. It is the author's conviction that the correct time of intervention, must be reconsidered. Treatment priority factors such as individual “maturity”, gender, presence of orthodontic alterations, can direct the treatment plan toward early labial frenectomy associated or not to orthodontic therapy. Indications for surgical removal of pathological frenum have been described [Olivi et al., 2006; Olivi et al., 2010] (Table 2).

The technique described is minimally invasive, safe,

easy to perform, repeatable and predictable for the post-operative period. This surgical protocol can be considered an innovative standard of care when pathological frenum conditions and treatment priority factors are present.

The use of laser has been studied for many years in oral surgery, also in the field of paediatric dentistry. Its effectiveness in performing precise surgical incisions and its haemostatic control is recognised to be a strong advantage in paediatric oral surgery [Olivi G. et al; 2009]. Among the other advantages of soft tissues laser surgery, many authors agree for a quicker and easier use, sutureless technique, less use of local anaesthesia, post-operative recovery often asymptomatic due to the decontaminating and the photobiomodulating effect of lasers. Especially in children, these advantages makes the difference for superior acceptance of laser techniques when compared to conventional surgery [Boj et al., 2005; Haytac et al., 2006; Genovese and Olivi, 2008; Kara, 2008].

Moreover the results of laser surgery are dependent upon the type of wavelength and technique used [Ishikawa et al., 2008]. The authors used a free-running pulsed Erbium:YAG laser (in the medium infrared electromagnetic spectrum) that targets the water content of soft and hard tissues. Laser technology allows the user to choose and vary different pulse duration modes, to better interact with soft tissues and periosteum. Also to

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| 1. Anomalous maxillary labial frenum (Class III and IV) associated with inflamed gingiva and gingival recession |
| 2. Anomalous and abnormal maxillary labial frenum (Class IV), associated to median diastema during mixed dentition, in patients needing orthodontic therapy |
| 3. Anomalous maxillary labial frenum (Class IV), associated to median diastema after complete eruption of the permanent canines |

TABLE 2 Anatomical and clinical indication for labial frenectomy modified from Olivi et al., 2006 and Olivi et al., 2010.

use the air-water spray delivered through the handpiece produces clean incision and vaporisation of the soft tissues first and permits safely working on the periosteum, limiting any rise in tissue temperature, thus avoiding any sign of carbonisation and thermal effect on the peripheral tissue [Boj et al., 2007; Olivi et al., 2010].

Other authors suggested the use of near-infrared or far-infrared lasers for a better control of bleeding [Baggett et al., 1999; Gontijo et al., 2005; Shetty et al., 2008], but it is the authors experience to avoid any thermal effect to the irradiated area and peripheral tissues that could delay the healing [Pié-Sánchez et al., 2012], and considers this choice unnecessary in most cases.

The technique used is aimed to be minimally invasive, avoiding any over-extension of the surgery, performing a standardised surgical design that is repeatable, leading to predictable post-operative symptomatology and healing. Minimally invasive surgical design includes a limited vertical extension of incision 1 toward the lip. A vertical over-extension of the incision does not add any benefit to the procedure, creates a greater wound, protracts the healing time and must be avoided. Also a horizontal over-extension of incision 2 toward lateral incisors is not useful and again creates a larger wound protracting the healing time.

On the other side, the complete vaporization of deep fibers in the surgical area, from the frenum palatal insertion site to the ideal insertion site at muco-gingival junction is important to avoid any re-attachment of connective fibers on periosteum. A slight incision on the periosteum along the muco-gingival junction, performed by Erbium:YAG laser with shorter pulse (100 microseconds) and water spray, helps to define the new attachment site of the frenum, marking a thin scar that stops the coronal migration of the frenum fibers. The Er:YAG laser use in this study carried out an important role in children surgical treatment, allowing considerable reduction of the operating time, reducing the amount of local anesthetic used as well as avoiding surgical sutures and thus improving patient compliance. The post-operative phase was always comfortable and well tolerated by the children thus avoiding the prescription of analgesics and making the procedure fully accepted.

Conclusion

Anomalous and/or abnormal labial frenulum associated with orthodontic problems in children can be resolved with early and minimally invasive intervention together with functional orthodontic therapy without postponing the therapy to teen-age when frenectomy and multiband fixed orthodontics will be required. The surgical technique presented in this article leads to predictable results, in terms of time and quality of tissue healing that responded with improved adherent gingiva growth, minimal presence of scar tissue and absence of recurrence. When

following the correct indication for labial frenectomy, this safe, easy and repeatable technique can represent a new standard for labial frenum surgery in children.

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