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NEW APPROACHES IN ORTHO-SURGICAL TREATMENTS WITH STIMULATE & INNOVATIVE TECHNOLOGY.

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INTRODUCTION

Orthodontic treatment is based on the principle that the prolonged application of a pressure on a tooth causes movement, through the remodelling of the surrounding alveolar bone. The bone is reabsorbed and produced selectively. In practice, the tooth moves inside the bone bringing with it its periodontal attachment system together with the alveolar process. The bone response is mediated by the periodontal ligament and we could therefore define the dental movement as a phenomenon primarily determined by this structure. [1]

Even during the dental movement that occurs physiologically in the dental eruption, the periodontal ligament is the main characters.

The phenomenon of dental eruption reveals that forces generated inside the periodontal ligament (PDL) can induce a dental movement. The mechanism of the eruption appears to depend on metabolic events internal to the PDL. These events include, among the various phenomena, the formation of collagen fibres, the appearance of connection ties and the maturation of the fibres themselves. [2]

In this study we performed a monitoring of dental movement in a particular condition: impacted palatally canines, only surgically treated with a new laser approach, without using any type of orthodontic traction.

The upper canines are among the most frequently impacted teeth and they are often located in the palatal site. Ectopic eruption and impaction of canines are frequently encountered clinical problems. The incidence of impaction ranges from 1% to 3%. The causes of the impacted canines are multifactorial. In fact, it has been found in literature that there are both local factors that can predispose to this, both of polygenic hereditary factors. Very often multiple dental anomalies are associated in the same patient. [2]

One of the treatment options for the impacted maxillary canine is surgical exposure followed by orthodontic forced eruption.

Several surgical techniques have been introduced in the literature for the exposure of the impacted canine. Careful clinical examination and proper diagnostic imaging should be used to define the anatomical position of the impacted canine. The surgical approach for exposure of impacted maxillary canines should consider the anatomical position of the tooth in relation to the alveolar ridge and the amount of keratinized mucosa/gingiva. [3]

In the combined orthodontic and surgical approach, the surgery provides the placement of an anchorage means and it is followed by the second phase, the orthodontic treatment, which consists in therapy with a fixed device that has the purpose of exerting traction on the canine.

In the conventional surgery the orthodontic therapy is used for the traction of the canine and as guide for the eruption.

The new surgical approach, performed on patients in this study, is a canine exposure through laser.

Lasers are a relatively new addition to the orthodontist's armamentarium. The contact cutting mode provides enhanced bloodless site visibility and easiness in performing delicate soft tissue procedures, mostly for difficult-to-access areas. [4]

Currently, the laser method is still in the experimental phase and this type of procedure produces the spontaneous eruption of the canine, with the only need of final alignment, with fixed bonding techniques, without the need to traction it.

The purpose of this study is to monitor the movement of the impacted tooth after exposure with laser approach.

The spontaneous eruption is evaluated in a sample of 10 patients over time, in which some of these had a double inclusion and others a single canine inclusion, all in the palatal site. This monitoring lasts 4-5 months depending on the patient's response and ends with the start of the alignment phase through the direct/indirect bonding technique.

Dental monitoring was performed with intraoral scans using the CARESTREAM 3500 intraoral scanner. The scanner application allowed us to measure all dental movements and compare them over time.

Intraoral photos and analogical impressions of patients were also taken at each control visit.

Monitoring by intra-oral scans and photos was performed according to the following timing:

- TIME 0: PRE-SURGERY
- TIME 1: 1 WEEK
- TIME 2: 8 WEEKS
- TIME 3: 16 WEEKS.

With this digital method it is possible to do an initial scan that provides a three-dimensional model of the patient's oral cavity before the surgery, that is matched with the following scans done after the surgery.

In this way, it is possible to evaluate any tooth movement expressed in angular and millimetric numbers, which are then interpreted by the orthodontist.

Another aspect of the study is focused on the differences between digital monitoring through scanner and the conventional monitoring which is based exclusively on the clinical evaluation of the photos and on the study of the plaster casts.

The popularity and availability of virtual technology in orthodontics for the replacement of hard-copy records with electronic records is growing rapidly, with a move towards a 'digital' patient for diagnosis, treatment planning, monitoring of treatment progress and results. [5]

The validity, reliability, and reproducibility of digital models obtained from the Intraoral scanner allows us to obtain dental measurements for orthodontic purposes. [6]

Making an accurate dental impression is one of the most essential and time-consuming procedures in dental practice. During this procedure, it is crucial to ensure the reproduction of the intraoral condition as accurately as possible. The accuracy of a dental impression is determined by two factors: “trueness” and “precision.” Trueness is defined as the comparison between a reference dataset and a test dataset. Precision is defined as a comparison between various datasets obtained from the same object using the same scanner. [7]

The scanner used is Carestream 3500, with it you can easily acquire precise dental coloured impressions, both 3D and 2D. The CS 3500 scanner is an open system scanner, the digital images obtained through scanning are in Standard Tessellation Language (STL) file format which can be easily shared with all the laboratories.

The study defines the eruption time after the laser surgery and determinate a proper time to move on the next step of orthodontic therapy, which is the bonding and alignment of the full dental arch. The aim of the study is to demonstrate the validity of the monitoring through intraoral scanner of the dental movements. Successively, the aim is to demonstrate the real importance, advantages and convenience, in term of treatment time gain, to frequently monitor a patient with a scanner application, which means:

- significant reduction in the mean period of chair time,
- less degree of discomfort for orthodontist and patient,
- reduction of the periods of orthodontic treatment,
- help the orthodontist to make clinical decisions supported by measurable data and not just by clinical experience.

CHAPTER 1: BIOMECHANICS OF DENTAL MOVEMENT

1.1 Role of the periodontal ligament

Each tooth is attached to the surrounding alveolar bone, and at the same time separated from it by a robust supporting collagen structure: the periodontal ligament (PDL). Normally the PDL occupies a space of about 0.5 mm around the root of the tooth. The main component of the ligament is represented by a set of parallel collagen fibres that insert on one side into the root cement and on the other side in a relatively robust bone surface: the hard lamina. These support fibres, in their attachment to the dental surface, have an oblique direction in the apical direction. This arrangement allows the tooth to oppose greater resistance to the forces that occur during normal chewing activity. [1]

Much of the PDL space is occupied by the tangle of collagen fibres that constitutes the tooth fixation system, but there are two other important components of the periodontal ligament: (1) the cellular component consisting of mesenchymal cells of various types, together with neural elements and vascular; (2) tissue fluids. Both play an important role during normal activity and in orthodontic movement. During the normal activity, a continuous remodelling of the alveolar process and of the root cement occurs. The fibroblasts of the periodontal ligament have characteristics similar to those of the osteoblasts and, differentiating themselves from the local cell population, form new bone. [8]

The alveolar bone- and the cement are removed, respectively, by osteoclasts and specialized cementoclasts. These plurinucleated cells have different origins than osteoblasts and cementoblasts that produce bone and cement. [1]

1.2 Dental eruption mechanism

The phenomenon of dental eruption reveals that forces generated within the PDL itself can induce dental movement. The mechanism of the eruption appears to depend on metabolic events internal to the PDL; these include, among the various phenomena, the formation of collagen fibres, the appearance of connection ties and the maturation of the fibres themselves. A similar process continues, albeit at a lower speed, even during adult life. The continued presence of this mechanism indicates that it can't only induce the eruption of the teeth in particular situations, but it can also favour its stabilization in relation to forces prolonged of slight entity. The active stabilization action implies the presence of a threshold for the orthodontic forces, below which they are ineffective to produce a dental displacement. The efficacy threshold for an external force should vary according to the pressure exerted by the tissues surrounding moles on the tooth stabilization system. It is currently believed that the active stabilization system can withstand prolonged forces of up to a few grams, perhaps up to 5-10 g / cm^2; in fact, this is the magnitude of the differential pressure exerted by the soft tissues on the teeth. [1]

1.3 Theories on dental movement

The two main theories concerning the orthodontic movement hypothesize different control systems: one based on biological electrical signals and the other on a pressure-tension mechanism inside the PDL.

- The bioelectrical theory partially attributes the dental movement to changes in bone metabolism, induced by electrical currents that are generated when the alveolar bone is subjected to flexion, which causes a deformation of the crystalline structure and the migration of electrons from one area to another one. The signals generated are piezoelectric. It has now been established that the signals induced by mechanical stress are essential for maintaining the normal skeletal structure. The absence of such signals causes the loss of the mineral bone component with consequent skeletal atrophy. It has been shown that a low-voltage electric current directly applied to the alveolar bone, modifying the bioelectric potential, induces a more rapid movement of the tooth to which a spring has been applied, with respect to the control tooth. [9][10]

  Electromagnetic fields can cause a change in membrane potentials and their permeability, thus inducing changes in cell activity.

- The theory of pressure-tension is based on the classical hypothesis that cellular differentiation and finally dental movement are controlled by chemical rather than electrical signals. There is no doubt that chemical messengers intervene in the succession of events that lead to bone remodelling and dental displacement. According to the theory of pressure-tension the dental movement is due to changes in cellular activities induced by chemical messengers, probably generated by changes in blood flow within the PDL. Continuous strength induces a modification of the blood flow in the PDL through a movement of the tooth inside the alveolus; this movement involves a compression of the ligament in some areas and a pull in others. The reduction (pressure) or the increase (tension) of the diameter of the vessels, follow the application of orthodontic forces. This phenomenon changes the extent of the blood and so the blood flow decreases in the compression areas of the PDL, while it is equal or increased in the traction areas. The oxygen tension decreases in the compression zones and perhaps tends to increase in the traction zones; similarly, changes in the levels of other metabolites can occur within a few minutes. These chemical changes can stimulate a particular cell differentiation directly, or through other biologically active substances. According to this hypothesis, the dental movement is performed in three stages: alteration of the blood flow consequent to the pressure exerted on the PDL, synthesis or release of chemical messengers, activation of specialized cells. [1]

These two theories are neither incompatible nor mutually exclusive. It is currently thought that both mechanisms come into play in controlling dental movement.

1.4 Biology of dental movement

When the pressure exerted on the PDL is excessive, there is a great reduction in the blood flow inside it, up to a complete collapse of the blood vessels and consequent ischemia. This result was obtained in experimental animals in which the increase in force applied to a tooth is accompanied by a reduced perfusion of the areas of PDL under compression. [1] [11]

When a light and continuous force is applied to the tooth, a reduction of the blood flow is observed through the PDL, the fluids are pushed out of the periodontal space following the movement of the tooth into the alveolus (in a few seconds). After a few hours the chemical changes occurred induce a different model of cellular activity: an increase in levels of cyclic adenosine monophosphate (AMPc), the "second messenger" of many functions involved in cell differentiation; this occurs approximately 4 hours after the application of a continuous pressure. [1][12]

Shortly after the application of pressure, the values of prostaglandins and beta interleukin 1, in the PDL, increase; in particular, it seems that prostaglandin E is an important mediator of cellular response. [13]

Changes in cellular shape probably play an important role. Prostaglandin release is believed to occur when cells are mechanically deformed (the release of prostaglandins may be a primary and not a secondary response to pressure stimulus). [14]

Other chemical messengers are also involved, in particular those of the cytokine family, but also nitric oxide (NO) and other regulators of cellular activity. [15]

To obtain a dental movement, osteoclasts are necessary. They remove bone tissue in the PDL compression area. It is also necessary that the osteoblasts place new bone on the tension side and intervene in the remodelling of the areas affected by the resorption on the pressure side. The cells attack the hard lamina through a process of "frontal bone resorption", which is followed by the dental movement. In the meantime, even if with some delay, osteoblasts (differentiated locally from progenitor cells present in the PDL) form new bone on the tension side and begin the remodelling activity on the compression side. [1]

The situation changes if the applied force is large enough to completely occlude the blood vessels in an area of the PDL. In this case, a sterile necrosis of the compressed area is obtained, the cellular component disappears, the avascular area in PDL is traditionally defined as area of ialinization. The osteoclasts appear in the neighbouring bone and begin to attack the outer side of the bone adjacent to the necrosis area. This process is described as indirect resorption (sub-dominant), as the attack starts from the outer wall of the hard lamina. As a consequence, the process of ialinization and the indirect reabsorption involve an inevitable delay in moving the tooth. [1]

1.6 Biomechanics of dental movement in orthodontics

A single force in practice almost never acts through the centre of resistance. Therefore, a single force results in displacement of the centre of resistance in the direction of the line of the force (tipping). This tendency for rotation is called the moment of the force whose magnitude is equal to the magnitude of the force multiplied by its perpendicular distance from the centre of resistance of the tooth. This application of a force will cause the centre of resistance of the tooth to move parallel to, and in the same direction as, the force. The centre of rotation will be located apical to the centre of resistance. [21]

The second method by which tooth movement can be performed is through the application of a pair of equal forces which are parallel, non co-linear, and of opposite direction, termed a couple. This system, applied anywhere on a tooth, creates only a tendency for rotation referred to as the moment of the couple whose magnitude is equal to one of the forces of the couple multiplied by the inter-force distance. The centre of rotation resulting from the moment of the couple is always coincident with the centre of resistance of the tooth irrespective of its point of application.

We can describe tooth movement as rotational (tipping) and/or translational (bodily movement). [21][22]

for translation to occur there must concurrently exist a couple with an opposite sense tending to tip the root in the opposite direction as the crown.

Under these conditions, the relative amount of crown tipping (moment of the force) and root tipping (moment of the couple) expressed at any moment in determines the location of an instantaneous centre of rotation. When these two oppositely directed moments are equal in magnitude, the centre of rotation is at infinity and tooth translation occurs (Figure 3). This determinant is also expressed as the moment to force ratio.[21][22][23][24]

For a ratio of 5/1 we will have an uncontrolled tipping of the crown, as for the single force. For a ratio of 5/1 to 9/1 we will have a controlled tipping in which the crown and the root move in the same direction. For a ratio of 10/1 and 11/1 we will have a translational body movement. For values of 12/1 we will have an uprighting of the root. [25]

CHAPTER 2: NEW DIGITAL TECHNOLOGIES IN ORTHODONTICS

2.1 Review of the literature on digital technologies in orthodontics

“It has been said that in life two things are inevitable:

death and taxes. May I add a third (though not so vital):
the application of the computer to orthodontic
research and diagnosis."
Wilton Marion Krogman, (forensic anthropologist)

These were the opening words of American Association of Orthodontists' annual meeting in New Orleans in May 1971. [26]

Digital technologies are nowadays widely used in the several branches of dentistry. By carrying out a literature review, various digital methods have emerged that have been applied in orthodontics, gradually modifying normal orthodontic practice in the last years, but the process has been slower in orthodontics than in other fields of dentistry.

These new technologies are: Invisalign or Clear Align method [27][28][29][30][31], CAD-CAM technology [26][30][32][33] associated to the manufacturing of these orthodontics devices, Cone beam technology [34][35][36][37][38], Intraoral scanner [13][14] for make impressions of the patients dental arch, new software to evaluate the dental movements [31][28][39] and to make cefalometric digital analysis [40][41][42][43][37], mobile application [37][44][45][39] for clinicians or for patients, and 3D images fusion technique [46][47][48][49][50][51][52][53].

2.2 CAD-CAM Technology

The first digital revolution took place many years ago with the production of dental devices and dental restorations using dental CAD–CAM system. New improved systems appear on the market with great rapidity.

Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) technology, already entrenched in dentistry since 1987 when Sirona introduced its CEREC units.

CAD/CAM gave practitioners a way to digitize study model data and incorporate those data into the patient's record. In 1999, Align Technology (San Jose, Calif) was the first company to offer a digitizing service (OrthoCAD) to the orthodontic community, followed by eModels (GeoDigm, Falcon Heights, Minn) in 2001. [30][37]

The development of CAD/CAM is based around three elements: (1) data acquisition, (2) data processing and (3) manufacturing. The exponential increase in power of computers has resulted in major advances in all these areas. [32]

Trough intraoral scanner is possible to create a 3D model of the oral cavity directly with such a system, without the need to take an impression, in alternative the model is then digitize with one of the many laser scanners that are now available. The digital model can be used to design the devices, like Invisalign aligners, trough many software packages available. [33]

2.3 Intraoral scanner

The new digital method of taking impressions of entire dental arches using the intraoral scanner was introduced in 1973, associated with CAD / CAM methods. This first device introduced was the CEREC marketed by Sirona Dental System. The first use in dentistry was within the conservative branch and then extended to other areas such as dental prosthesis and orthodontics. The first orthodontic scanning system OrthoCAD developed by Cadent was introduced in 1999. The application of this devices in dentistry has grown considerably in the last few years. [54-56]

The replacement of alginate and polyvinyl siloxane (PVS) impressions with intraoral digital scanners represents a paradigm shift in orthodontics. Using this technology, orthodontists can more accurately and efficiently fabricate clear aligners, custom braces, indirect-bonding trays, and laboratory appliances without the unpleasant experience of conventional impressions. [57]

Every scanner has three major components: a wireless mobile workstation to support data entry; a monitor to enter prescriptions, approve scans, and review digital files; and a handheld camera wand to collect the scan data in the patient’s mouth.

To gather surface data points, energy from either laser light or structured light is projected from the wand onto an object and reflected to a sensor or camera within the wand. Based on algorithms, tens or hundreds of thousands of measurements are taken per inch, resulting in a 3D representation of the object’s shape. [57]

A point cloud is linked through the algorithm to form a 3D model in a standardized triangular language.

2.3.1 Applications of intraoral scanner in orthodontics

Digital scanning can be used in orthodontics for a variety of applications.

Some applications have been described for treatment planning [58], indirect bonding tray fabrication [59], palatal and lingual custom appliance design and construction [59], clear aligner technology [60], orthognathic surgery simulation and wafer construction [61,62] and more recently, the scoring of surgical outcomes in patients with Cleft, Lip and Palate abnormalities. [56,62]

New technologies are increasingly used in the field of orthodontics, given their digital impressions were found useful also for diagnosis and patient monitoring development and the increase in effectiveness.

To this end, many of the scanner companies are developing 'comprehensive' integrated packages as orthodontic practices and clinics change from hard copy records to the 'digital patient'. [56]

Although there are also some disadvantages, intraoral scanning technology holds great potential to increase efficiency for orthodontic practitioners and may eventually take the place of impressions. [63]

2.3.2 Comparison between conventional impression and digital scan

Alginate and PVS impressions have been associated with problems such as pulls, tears, bubbles, voids, tray-to-tooth contact, separation from the impression tray, temperature sensitivity, limited working time, material shrinkage, inaccurate pouring, model over trimming, and breakage during shipment. [64] Impression taking also heightens anxiety and discomfort for patients of all ages, particularly those with sensitive gag reflexes. In vitro studies have shown that full-arch digital scans are as accurate as conventional impressions [65] without these drawbacks.

Lee and Galluci [66] conducted a study to assess the efficiency, difficulty, and operator's preference of an intraoral digital impression and compared it to a conventional impression for single implant restorations. The results indicated that total treatment time was 12’29” for digital and 24’42” for conventional impressions; and time of rescan/retake was 1’40” for digital and 6’58” for conventional impressions. Although the total number of digital impressions rescans was more than that in conventional impression. This pilot study reached a conclusion that there was a significant difference in operation time between these two impression methods.

Participants were asked to answer visual analogue scale (VAS) and multiple-choice questionnaires to evaluate their perceptions of difficulty, preference, and proficiency for both impression techniques. The results showed that the grade of difficulty was lower for the digital impression than that at the conventional impression. The digital impression techniques were more acceptable and easier to grasp. [67]

According to another study the mean chairside time required to perform alginate impressions was significantly (P-value 0.0001) shorter than the mean chairside time required to perform intraoral scans. When the processing times were included, the time requirements for impressions and intraoral scans did not differ significantly (P-value 0.0649). [73]

2.3.3 Advantages and disadvantages of digital impression

For the orthodontist, advantages of digital scanning include improved diagnosis and treatment planning, increased case acceptance, faster records submission to laboratories and insurance providers, fewer retakes, reduced chair time, standardization of office procedures, reduced storage requirements, faster laboratory return, improved appliance accuracy, enhanced workflow, lower inventory expense, and reduced treatment times. Benefits to the patient include an improved case presentation and a better orthodontic experience with more comfort and less anxiety, reduced chair time, and easier refabrication of lost or broken appliances, as well as potentially reduced treatment time. [57]

In particular, young children, patients with clefts of the lip and/or palate and those with a heightened gag reflex express a dislike for traditional impressions. Recent investigations have shown 3D scanning to be more acceptable in terms of patient perception and comfort over traditional impressions. [68,69]

However, recent research has highlighted that 3D model scanners with an accuracy of at least 20 mm are suitable for assessing archform in patients with cleft lip and or palate. [56,70]

Digital scanning reduces risk of allergy when compared to the small but none-the-less pertinent risk posed by the many constituents of impression material. [71]

It has been shown in the literature that digital impression represented a remarkable superiority in efficiency over conventional impressions.

The digital impression took less time for rescans despite a larger volume required, because in this type of impression, only the missing and unacceptable areas were rescanned, contrary to the conventional ones in which, the entire arch needed to be retaken. [67,72]

However, some studies do not support these advantages, conventional impressions were favoured over intraoral scans by most patients, primarily because they were "easier" or "faster". [63] This contrasts with other study in which most of the participants preferred the intraoral scans. [73]

Another discomfort was related to the dimensions of the scanning tip and its interference with the patient's coronoid process. As scanning technology continues to evolve, the design of a thinner scanning tip may improve comfort and increase patient acceptance of the scanning procedure. [63]

An aspect to take into consideration is the high cost of the intraoral scanner and of its updates, as well as the fact that the staff must be instructed to the correct use of the digital device.

2.2.6 Accuracy on intraoral scanner application

Accuracy consists of precision and trueness (ISO 5725-1). [69] Precision describes how close repeated measurements are to each other. [70] Therefore, a scanner with higher precision correlates to a more repeatable and consistent scan. [70] Trueness describes how far the measurement deviates from the actual dimensions of the measured object. [80] Therefore, a scanner with high trueness indicates that the scanner delivers a result that is close or equal to the actual dimensions of the object being scanned. [70,71]

There are two ways to create a digital impression: direct intraoral scanning or indirect extraoral scanning gypsum casts. [72]

Accuracy could be assessed as the agreement between the digital models in STL acquired using the intraoral scanner and the corresponding models that had been acquired with either the alginate impressions. [73]

A direct intraoral scanning is truly free of a physical impression so that it is able to get rid of the errors derived from the distortion of elastomeric impressions, disproportionate water/powder ratio of dental plaster and unsuitable storage conditions of physical impressions or gypsum casts. [74,75]

With digital models fabricated from alginate impressions, fine details of tooth anatomy might be lost because of the limited ability of the impression material to flow into areas with undercuts, and potential shrinkage upon desiccation can compound the problem. [76,77,78] Additional loss of information may be related to the scanning process because the accuracy of a digital model is limited by the resolution of the scanner that recorded it. [63]

However, intraoral scanning can result in digital models that more accurately represent the intraoral situation because there are fewer sources of error. It is logical to assume that when processing steps are eliminated in the production of digital models, the models will be more accurate.

2.4 CBCT in Orthodontics

The CBCT uses a cone shaped X-ray beam and one large 2D detector to capture the cone shaped beam. The 2D detector can record a large (e.g. 16 cm 22 cm) area of the face in one or two rotations (20–40 s), this type of CT reduces the effective radiation dose as compared to MSCT scanning. [34]

The use of Cone Beam Computerized Tomography (CBCT) has allowed for accurate visualization of the roots of teeth in 3 dimensions. However, a CBCT scan uses significantly more radiations than does a panoramic radiograph, so multiple CBCT scans would not be suggested clinically. An imaging technique that can be performed more times during orthodontic treatment without radiation is a digital intraoral surface scan. This technique can accurately display crowns with high resolution, but it cannot show the roots. Since neither CBCT and digital intraoral surface scans can safely and accurately visualize root positions at different stages of orthodontic treatment, root tracking might be possible with a combination of these two imaging techniques. [35]

From the CBCT it's possible to generate a three-dimensional virtual model of each teeth, and this can be superimposed with the crown of the same teeth obtained by intraoral surface scan models.

The current standard of care suggests the use of panoramic X-rays to monitor root alignment, even though many studies have shown that panoramic X-rays do not accurately depict root positions and angulations due to their two-dimensional projection. [36] It seems to be clear that a new approach in monitoring accurately our treatments is necessary. [35]

An appealing aspect is that a CBCT scan could serve as a patient's singular data set from which to derive all the traditional views of an orthodontic workup. [37][38]

By CBCT scan of the patient it's also possible to obtain a 3D volume model of the full arch, using many programs that can convert CBCT files to STL files.

This digital method allows, as was done in this study, to use the three-dimensional file obtained from the CBCT for overlapping with the files obtained from intraoral scans to monitor the real movement of dental eruption obtained during treatment. It also allows us to compare the position of the root of the tooth at the beginning of treatment with that at the end of the treatment obtained from the superposition with the erupted crown of the element.

CHAPTER 3: IMPACTED PALATALLY CANINES

3.1 Introduction on impacted canines

Impacted teeth are often encountered during the diagnosis and treatment of malocclusions in adolescent orthodontic patients. After the third molars, the most commonly impacted tooth is the maxillary canine with an incidence of 0.9% to 2.2%, [79-82] which varies depending on the ethnicity of the sample population.

Although the canine crown can be impacted either labially or palatally, it is more frequently positioned in the palate. [83,84]

Of all patients who have impacted maxillary canines, 8% have bilateral impactions. [80,85] There are most common in female than in male patients. [80]

Tooth impaction can be defined as the lack of presence in the oral cavity of an element that has completed its morpho structural development within the osteo-mucous structure, at the end of the period provided for its physiological eruption. The position of the tooth is intraosseous, whereas the anomalous intraosseous position of the canine before the expected time of eruption can be defined as a displacement. Most of the time, palatal displacement of the maxillary canine results in impaction. [86] In the impacted tooth the root apex is closed, with absence of the vis a tergo which is typical instead of the dental elements retained.

3.2 Etiopathogenesis of upper impacted canines

The causes of inclusion are multi-factorial. For upper canines in particular, one of the predisposing factors found is the difficult eruptive path. The canine must make a long path (about 22 mm) [80,87], being its gem located below the orbital margin, laterally to the piriform fossa, and therefore in a location far from that of eruption. [88]

During its physiological path the tooth moves downward, mesially inclined towards the root of the lateral incisor. There is a phase between 8 and 10 years that is called the ‘ugly duckling dentition’ in which appears a diastema precisely because of the push of the crown of the canine on the apical part of the root of the lateral incisor, above the rotation centre of the tooth. After this phase, the canine continues its path along the distal surface of the root of the lateral incisor, thus closing the diastema. [80,88]

Another predisposing factor is that canines have the longest period of development. [80,87]

Broadbent speculated that because of the long path of eruption and so long period of development taken by the maxillary canine, it had a greater chance of inclusion. [89,90]

There are two main theories on the inclusion of these dental elements: the genetic theory and the guidance theory.

- The genetic theory states that maxillary palatal impaction has familial and hereditary component and includes other associated dental anomalies, such as missing or small lateral incisors. [91] Additionally, impaction of upper canines is correlated with enamel hypoplasia, infraocclusion of primary molars, aplasia of second premolars and small size of maxillary upper lateral incisors. [92,93]

- According to the guidance theory, the canines erupt having as their guide the distal side of the root of the lateral incisor. If it is absent or malformed there is an alteration of the eruption path of the canine.[92,94,96,97] As a matter of fact, maxillary lateral incisors are also among the most frequent with a deficient form, with small and peg-shaped crowns, and it has been confirmed as representing a microform or a lesser degree of severity of agenesis. [89]About 50 years ago, Miller and Bass independently observed that the prevalence of palatal displacement was greater when lateral incisors were congenitally missing. They concluded that the absence of the lateral incisor denied the canine its guidance, permitting it to migrate palatally. [89,97,98]

Lappin et al. [99] observed clinical and radiographic assessment of a number of impacted canine cases correlated with deciduous canines frequently over retained, often with a long and unresorbed root.

He speculated that the non-resorption of the deciduous canine was the cause of the anomaly. We know that the mechanism for root resorption require that an unerupted permanent tooth is near to the deciduous root. Thus, it is plausible that resorption has not occurred because of the distance of the permanent tooth, and so the unresorbed

root of the deciduous canine is not the cause of the displacement, but rather its result. [87] Various local factor may interfere with the normal eruption, because of the long path of the canine predisposes to a greater probability of encountering obstacles.The first entities that come to mind are the supernumerary tooth and the odontoma. [100]
When these etiologic factors are eliminated, there is a degree of autonomous correction in the eruption path that may lead to spontaneous eruption of the canine. [89]

Other local factors are a chronic periapical granuloma, that has a potent effect on deflecting or arresting the eruption of the permanent canine [89];and a trauma to the face, that can cause displacement of the unerupted canine or dilaceration of its developing root. [101,102]

Also, some skeletal abnormalities can be predisposing to the impaction of this tooth as class II division 2 malocclusion, a deep overbite, a hypodivergent profile, and abnormal maxillary width.

3.3 Prediction of inclusion

The inclusion of the canine can be predicted according to Lindauer, that modified the analysis of Ericson and Kurol, in the period of mixed dentition using the opt. On this radiography it is possible to evaluate it, dividing the frontal area into 4 sectors (I-II-III-IV), delimited by three lines:

- the tangent to the distal surface of the crown and the root of the lateral

- the central axis of the lateral incisor

- the tangent to the mesial surface of the crown and the root of the lateral.

The probability of inclusion will be greater if the crown of the canine is mesio-inclinated respect to the long axis of the lateral incisor and if it is moving from the distal sectors to the mesial. This prediction is not completely reliable, but it can be considered at least indicative. [102]

3.4 Diagnosis of impacted canines

Tooth impaction is generally asymptomatic, and in most cases, the diagnosis occurs during a routine check-up by general dentists or orthodontists. [93,102]

Early detection of the included canines is essential to improve the prognosis of the dental element and to avoid all the consequences that are related to dental inclusion.

We should have the suspect of the impaction in the intra-oral objective examination. Usually there is a persistence beyond the natural limits of exfoliation of the deciduous element, and a failure to erupt of the corresponding permanent. [80] It is also possible to make a comparison with the contralateral element, in the case of a single inclusion, which will be erupted.

Furthermore, the malposition such as rotations or malformation of the adjacent teeth, the absence of a normal labial canine bulge and the presence of a palatal bulge suggests the possible impaction of the canine.

After the intraoral examination, radiographic examinations are carried out to confirm the diagnostic hypothesis.

The radiographs taken are opt, periapical and occlusal endorals. Nowadays three-dimensional radiographic exams, such as computerized tomography (CT) or cone beam computerized tomography (CBCT), is considered the best diagnostic tool to assess tooth impaction. [84,103,104,105]

The radiographic check-up is crucial to evaluate the anatomy of the impacted canine and to identify its location, inclination, and position, which will condition the type of operation and the orthodontic device to be used. With intraoral radiograph we can evaluate the morphology and the seat, but being the two-dimensional examination, it is important to perform at least two radiograms with the tube shift technique to establish the mesio-distal and vestibulo-oral position of the tooth. [102]

3.5 Prognosis of impacted canine

Ericson and Kurol reported that the degree of mesial overlap of the maxillary canine relative to the adjacent lateral incisor plays a role in the severity of impaction and the probability of spontaneous eruption. In 1988, they defined number of sectors to denote different types of impaction. [106]

- Sector 1: if the cusp tip of the canine is between the inter-incisor median line and the long axis of the central incisor;
- Sector 2: if the peak of the cuspid of the canine is between the major axes of the lateral and central;
- Sector 3: if the peak of the cuspid of the canine is between the major axis of the lateral and the first premolar.

They used angle "α" to represent the angle formed between the inter-incisor midline (as the perpendicular distance respect to the occlusal plane).

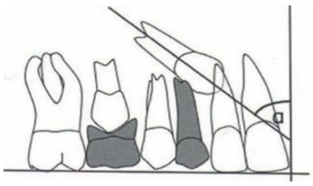


Fig. 1 - Angle "α"

The localization with sector methods has a more prognostic than diagnostic value.

In the year 2003, Warford et al., [107] did a study for predicting the maxillary canine impaction using sectors and angular measurement. He localised the canine according to 4 sectors and measured the angle between the bicondylar line and long axis of canine. He concluded that the probability of canine impaction increases as the angle reduces and the sector increases.

3.6 Approaches of disinclusion of palatally impacted canine

The treatment of impacted teeth requires multidisciplinary cooperation between orthodontists, oral surgeons and sometimes periodontists. Orthodontic treatment and surgical exposure of impacted teeth are performed in order to bring the impacted tooth into the line of the arch. The treatment is long, more complicated and challenging. [114]

The choice of the approach depends on a variety of factors including position of the canine, the associated malocclusion, the skill and experience of the orthodontist and surgeon, and anticipated patient compliance. [108]

The combined surgical-orthodontic approach relocates the impacted canine in its proper place in the dental arches.

The two major surgical techniques are the open and the closed technique. [109-113]

- The open technique involves exposing a palatally displaced canine by a circular incision (operculectomy) to remove bone and soft tissue directly overlying the impacted canine. Thus, the area of palatal mucosa which covers the crown of the tooth is cut out to create a window, through which the crown is visible. Afterward an attachment, such as an eyelet or a button, can be bonded at the time of surgery and orthodontic traction may be performed immediately. At the end, surgical pack might be used to cover the exposed area and it is removed in a few days. In this technique, the canine tooth moves into its correct position above the mucosa. [113-115] In case of bonding failure, there is no need for a second surgical exposure, but on the other side it can result in poorer periodontal outcome, increased risk of infection, greater discomfort to the patient, more extensive removal of alveolar bone, risk of closure of the exposure, increased bonding failure. [93,100]

- The closed technique involves surgically exposing the crown of the impacted tooth raising a full muco-periostal flap, removing the bone that cover the impacted tooth with a low speed bur and eliminating the pericoronal tissue using a periodontal curette. [116] Then an orthodontic eyelet or a button is applied and bonded on the crown while a wire chain is fixed to the attaching device. The palatal flap is then replaced and sutured leaving the length of chain to exit the gingivae. A few days after the surgery, gentle orthodontic traction can be applied to the tooth to start bringing in into its correct position within the dental arch. In the closed technique, the canine tooth is orthodontically moved into its correct beneath the mucosa. This approach is usually favoured when the tooth is more deeply embedded in the bone since open surgical exposure may necessitate excessive removal of the surrounding bone. [113-115] Some advantages are less discomfort, good postoperative homeostasis, less intense functional disturbances, less extensive removal of alveolar bone, possibility of an immediate traction, applicable close to resorbing root.

Mechanical eruption of palatally impacted canines may lead to prolonged treatment. Treatment times are thought to increase further with greater vertical and mesial displacement, increased angulation of the canine and increasing age. [108,117,118]

Deleterious effects of prolonged orthodontic treatment are well-documented and include the propensity for greater root resorption and poor patient compliance. [108,119] Additionally, root resorption of teeth neighbouring the impacted tooth is thought to be accelerated if mechanical eruption is undertaken. [108, 120]

In principle, in the treatment of an impacted canine in a superficial position, the open technique can be advantageous, as it allows a complete exposure of the crown and a simple and accurate bond placement. With deep impactions, closed exposures are usually favoured as open exposures may necessitate excessive bone and soft tissue removal risking periodontal damage to the impacted tooth or neighbouring roots. Incorrect positioning of attachments in closed techniques may be undetected until the canine has been erupted, generating unwanted rotations and prolonged treatment. Before the intervention it is important to create the space to place the included tooth in the arch, or if it is already present, this space must be maintained. Bracketing the upper arch provides to increase the space needed and to obtain an adequate anchorage for traction of the impacted canine. The primary canine will be extracted at the time of surgical treatment. [116] After surgery, orthodontic treatment involves pulling the canine on the palate and then the centre of the dental arch, with several methods .Elastomeric traction is useful to initiate eruption in conjunction with fixed appliances and stainless steel archwires. Rigid stainless-steel base archwires (e.g. 0.018-inch) are desirable to minimize reactionary forces reinforcing vertical anchorage. [121] Auxiliary NiTi archwires provide inherent flexibility to continue the eruptive process. [122,123]

3.6.1 Autonomous eruption

In addition to the guided orthodontic eruption, Kokich recommend an alternative technique for treating a palatally impacted canine: to surgically uncover the tooth and allow it to erupt autonomously before beginning orthodontic treatment.

With this procedure, a mucoperiosteal, envelope flap is elevated starting apical to the gingival sulcus on the lingual surfaces of the maxillary lateral and central incisors in the area of the palatally impacted tooth. Once the flap has been elevated, there is typically a thin layer of bone covering the lingual surface of the canine crown. This bone can be removed with either a curette or a handpiece and bur. Then, a bracket or cleat is bonded to the lingual surface of the canine crown.

The flap is repositioned over the tooth and a small hole is made in the gingival tissue over the canine crown, so the tooth will have no impediment to erupting autonomously. This open surgical defect is covered with a dressing that is mechanically attached to the lingual bracket or cleat. Then, this tooth is allowed to erupt. With this technique, if sufficient bone is removed, the palatally impacted canine will typically erupt autonomously to the level of the occlusal plane within 6 to 9 months. Then, the canine can be moved laterally toward the alveolar ridge. During this type of movement, the root is moving through the bone facilitated by the surrounding periodontal membrane.

No other types of treatment for the impacted palatally canines were found in the literature on PUBMED and SCOPUS.

In this study, we monitored the dental movement in patients treated with a new approach: laser surgery. This technique is still experimental and has numerous advantages over conventional surgical technique. The laser used in this study allowed us to expose the crown of the canine and biostimulate the area around it.

We used the carbon dioxide laser and diode laser.

There are no studies in the literature on this, but the laser is widely used in the dental field for its many benefits:

- Soft-tissue excision is more precise with a laser than a scalpel. [125,126]
- A laser coagulates blood vessels, seals lymphatics, and sterilizes the wound during ablation, maintaining a clear and clean surgical field. [125,127]
- Laser surgery is routinely performed by using only topical anaesthetic. [125,128]
- There is markedly less bleeding, minimal swelling, and no need for irritating sutures or unsightly periodontal dressing.
- Post-surgically, patients report less discomfort and fewer functional complications (speaking and chewing) and require fewer analgesics than do patients treated with conventional scalpel surgery. [129]

In dentistry, the laser is used with the continuous emission and pulsed emission mode. [146]

The first allows the maximum surgical precision while with the pulsed emission are possible interventions with no use of infiltrative anaesthesia both for the brevity of the pulsations (which are hardly perceived by the nerve receptors) and because the period of thermal relaxation between a pulsation and the other it protects fabrics from strong temperature increases. [129]

3.7 Laser application on dentistry

The application of the laser on soft tissue includes wound healing, removal of tissue that surround an impacted or a partially erupted tooth (operculectomy), photodynamic therapy for malignant lesions, photostimulation of herpetic lesion. [131] Lasers can be used to ablate large areas of gingival proliferation in a totally bloodless manner (gingivectomy, gingivoplasty and other periodontal procedures), to cut maxillary and mandibular frenae (frenectomy) and also both incisional and excisional biopsies can be performed with lasers, taking into account the slight thermal damage at the margins. [153]

The laser in orthodontics find its application also because of a new and promising concept emerged: photo-biomodulation or low-level laser therapy (LLLT) can accelerate tooth movement.

According to some works, laser has a bio-stimulatory effect on cellular regeneration, which has been shown in the midpalatal suture during rapid palatal expansion [133,134] and also stimulates bone regeneration after bone fractures and extraction site. [134-136]

Laser light stimulates the proliferation of osteoclast, osteoblast, and fibroblasts, and thereby affects bone remodelling and accelerates tooth movement. The mechanism involved in the acceleration of tooth movement is due to production of ATP and activation of cytochrome C.

This stimulation of dental movement by the laser is a factor that could make the orthodontic treatment after the operation less complicated and quicker. The monitoring that we carried out after the operation evaluates the spontaneous movement of the canine after the use of the laser, without an orthodontic anchorage appliance.

CHAPTER 4: MATERIAL AND METHODS

4.1 Aim of the study

The aim of this study is to show the effectiveness of laser technology for the exposure of the palatally impacted canines, using a CO_2 laser device (Smart US20D®, DEKA - Florence, Italy) and Diodi Laser device (Raffaello, DMT, Lissone, Italy, 980nm +645nm), which can stimulate the spontaneous eruption of the canine, without orthodontic traction application[137-139]. Moreover, the purpose of this study is to monitor the movement of the impacted tooth after exposure with laser approach with digital technologies.

Another aspect of this study is focused on the differences between digital monitoring through scanner and conventional monitoring which is based exclusively on the clinical evaluation of the photos and the study of the plaster casts[140-142].

4.2 Study design

The study was carried out on patients referred to the Orthodontics UOC of the Department of Odontostomatological and Maxillo-Facial Sciences of the “Sapienza” University of Rome. The period of recruitment of the patients was 1 year.

All the patients were informed about the content of the study, treatment methods, and potential risks and benefits, before providing written informed consent to take part in this study. The study received approval from the Ethical Committee of Sapienza University of Rome (#4389) and was registered in the international public register.

A preliminary investigation was performed to estimate the power of the study (PS) and to establish the effect size (ES) of the population sampled for the experimental study. It was calculated a statistical significance to determine an exact number of patients to become a study.

Suppose we want to estimate the prevalence of a disease (impacted canines) in a population. Through the study of the sample we want an estimate of the prevalence with a certain precision and a chosen level of confidence. The size can be calculated, with a 95% confidence level, using the following formula:

dimensione del campione

prevalenza attesa

$$n = \frac{1.96^2 P_{att} (1 - P_{att})}{D^2}$$

precisione assoluta desiderata

In our case with 95% confidence level and this data, when:

P_att: 96.5% (0.965)
D: 10% (0.1)

Therefore:
n = (1.96 ^ 2 * 0.965 * (1-0.965) / 0.1 ^ 2 = 12.97
That is 13

If the sample size recommended was >5% compared to the population from which it is extracted, its sample size could be reduced; with the statistical analysis, it was obtained that the sample size significance for this study was 13 canines.

The inclusion criteria considered in the experimental study design were:

- patients affected by palatally impacted canines;
- male and female;
- age between 12 and 25 years;
- patient will be reliable for follow-up;
- understands the protocol and can give informed consent.

The Exclusion Criteria were:

- Non-cooperative patients;
- inoperable patients;
- vestibular impacted canines;
- mandibular impacted canines;
- systemic pathologies;
- subject in drugs therapy.

These criteria resumed in the flowchart table:

CONSORT FLOWCHART

The final experimental sample was constituted of 18 patients, 9 females and 9 males; of these 8 patients showed a bilateral inclusion and 10 a mono-lateral inclusion of the canine, for a total of 26 canines. The age of the selected patients is between 12 and 22 years. Patient characteristics that were collected are: age, sex, number and location of the impacted canines.

The 18 selected patients, who make up our study group, were divided into two groups, randomly, treated with two different laser types:

- **GROUP A** (9 patients; 13 impacted canines): treated with CO2 laser (SmartXide®, DEKA, Florence, Italy, 10600 nm) with a power of 4.5 Watt in superpulsed mode (frequency: 80 Hz, fluency: 44.78 J / cm2, spot diameter: 400 µm.

- **GROUP B** (9 patients; 13 impacted canines): treated with Diode laser

Figure 2.CO_2 laser (SmartXide®, DEKA)

(Raffaello, DMT, Lissone, Italy, 980nm + 645nm) with a power of 4 Watt in

continuous mode (fluence: from 0.1 J / cm2 to 10 J / cm2).

Figure 3. Diode Laser (Raffaello, DMT)

To demonstrate the validity of the technique applied to the study group, a **CONTROL GROUP**, which included 9 patients with unilateral and bilateral palatally impacted canines (in total 13 canines), treated by a traditional surgical-orthodontic approach, was observed.

4.3 Analysis of radiographs

An RX orthopantomography and a CBCT were requested from patients at the beginning of therapy, to accurately evaluate the cases before surgery.[14] An evaluation of the prognosis of impacted canines was performed on OPT by two orthodontists, according to Ericson and Kurol.

Figure 4 – Rx orthopantomography

The major axis of the canine and the perpendicular to the alveolar margin were plotted on the OPT, imagining this as the axis of the canine in its presumed ideal seat. Subsequently, it was considered the height of the canine’s crown relative to the roots of the contiguous elements, which ideally should be between the third occlusal of the root of the central incisor and the mesial side of the root of the first premolar. Considered that the degree of mesial overlap of the maxillary canine, relative to the adjacent lateral incisor, plays a role in the severity of impaction and in the probability of spontaneous eruption, it was also evaluated the mesio-distal position of the canine's cusp, which could stay in four sectors.

The examination of the CT allowed to evaluate the three-dimensional morphology of the impacted tooth, its location and inclination in the three planes of space, the depth and the type of inclusion, the relationships with the other elements.

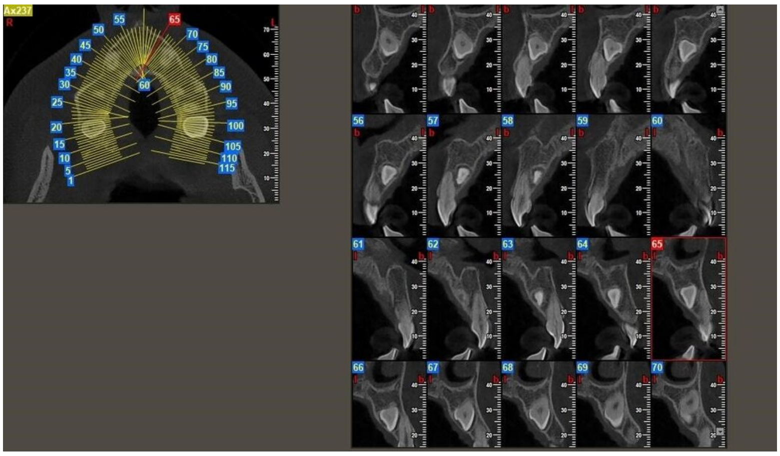


Figure 5– CBCT cross section

4.4 Steps of the surgery

The surgery was performed with an experimental laser disinclusion approach, using laser to make opercolectomy. The treatments were carried out by the same operator with the following procedure.

4.4.1 Local anesthesia

Before surgery, local anesthesia is performed at the level of the palatal mucosa.

For group A, local anesthesia was performed using a Mepivacaine 2% solution with Adrenaline 1: 100,000, 1.8 ml solution for injection, (Pierrel Spa, Milan, Italy).

For group B, a solution of Mepivacaine Pierrel - 3% without adrenaline, 1.8 ml solution for injection (Pierrel Spa, Milan, Italy) is used.

Figure 6 – Local anesthesia

4.4.2 Operculum

For group A, the operculum was performed with CO_2 laser, whose tip is used not in contact with the tissue surface during the rotary movement necessary to expose the crown of the impacted tooth.

Figure 7- Tissue incision by CO_2 Laser

For group B, the operculum was performed with the Diode laser, whose tip is used in contact with the tissue surface during the rotary movement necessary to open an operculum in correspondence with the crown of the impacted tooth.

The palatal mucosa overlying the tooth is then detached with a Prichard periosteal elevator and removed by the laser's cutting action.

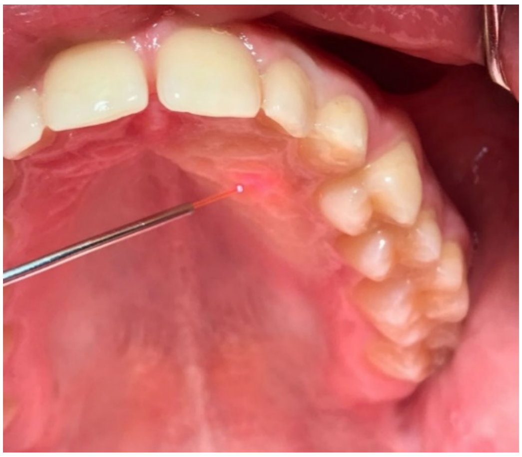


Figure 8- Tissue incision by Diode laser

Figure 9 - Drawing of the operculum

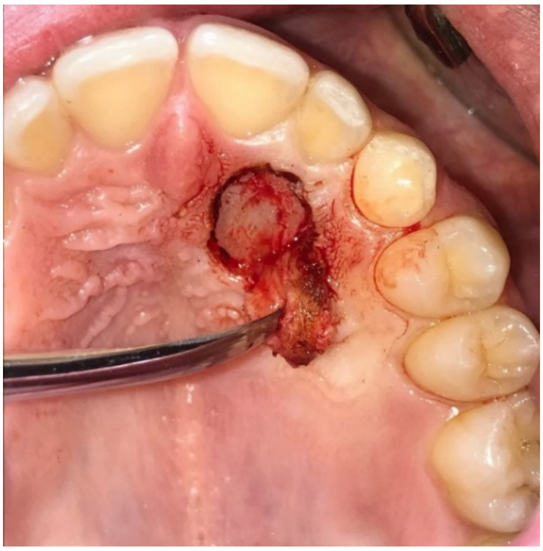


Figure 10–Operculectomy

4.4.3 Ostectomy

In both groups, in case the impacted tooth is covered by bone, it is necessary to carry out the exposure of the dental crown through a hand-piece at low speed and under abundant irrigation, with a rosette bur.

The drill is used with a tangential sliding movement to the bone tissue, in order to gradually remove it until the canine's surface is covered, which must not be damaged.

4.4.4 Periodontal dressing

At the end of surgery, a periodontal pack (Coe-pack, periodontal dressing regular, base 90 g + catalyst 90 g) was placed to protect the treated area of the palate.

It was left on site for about seven days, blocked from a suture point in Vicryl 3.0 Ethicon V311H 3/0 SH-1 70CM, Braided suture composed of a low molecular weight polyglactin copolymer of 910 and covered with polyglactine 370 (50%) and calcium stearate (50%).

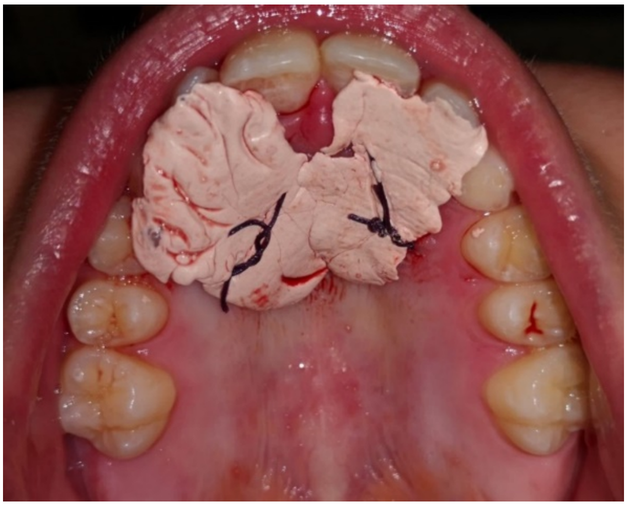


Figure 11- Application of the Coe-pack

At the end of the laser treatment, patients were informed about the need to avoid the intake of hot, spicy and hard foods in favour of cold and soft foods and to stop the brushing in the area undergoing surgery for 24 hours.

The control group was treated with traditional cold blade surgery.

In the superficially impacted canines, it was sufficient to draw an operculum with the scalpel to expose the canine crown, similarly to how it is performed with the laser in groups A and B, without the use of a mean of traction.

Figure 12 – Control group: traditional cold blade surgery in a patient with two superficially palatal impacted canines

In cases where inclusion was deeper, a flap has been performed, whose design and extension were different depending on the site and if the inclusion was unilateral or bilateral. For bilateral palatally impacted canines, a full thickness muco-periosteal flap was raised from the mesio-palatal surface of the second premolars. In unilateral cases, the flap extended to the mesio-palatal surface of the contralateral lateral incisor.

The bone tissue above the canine was removed with a rosette bur on high speed handpiece and his crown was exposed.

In the deep impacted canines, the orthodontic anchorage and the relative traction thread were applied, and the flap was sutured, making an operculum in correspondence with the ostectomy, to allow the passage of the traction wire.

The anchoring applied was a button or an orthodontic bracket if the exposed dental surface allows its application.

The intensity and duration of the force were modulated for the entire disinclusion phase. The applied force was initially very light (20-30 g) and then gradually increased during traction until reaching a maximum of 60-80 g. The traction device has been appropriately activated every month.

Figure 13 – Traction device applied to disinclude two deep impacted canines

At the end of the orthodontic traction of the impacted tooth, brackets have been applied on the upper arch, in order to align the now disinclused tooth in the arch.

4.4.5 Alignment in arch with the Damon System

When the canine has erupted sufficiently into the palate, in an ideal period of four months (16 weeks), a bracket or an orthodontic button is placed on the tooth and the upper arch is bandaged with Damon System technique[143-144]. In this way the tooth can be gradually translated into the dental arch.

Figure 14 – Damon fixed appliances

The Damon System is an orthodontic method that uses passive self-ligating attacks, designed by Dr. Dweit Damon, associated with high-tech wires in copper-nickel-titanium alloy.

Self-ligating devices are a system of direct attachments that do not require elastic or metal ligatures to keep the arc in the slot, having a door or clip mechanism designed to perform this function.

If the primary canine was present, it was extracted when the permanent approaches its final position in the dental arch.

4.5 Monitoring of dental movements

Post-surgery, the patients underwent three follow-up appointments, in order to evaluate and monitor the spontaneous eruption of the canines, or the eventual early closure of the mucosa and lack of appearance of the element in the palate.

During each control visit, a clinical examination, conventional impressions and intraoral scans was carried out, photographs were taken and questions were asked to patients regarding the presence of pain, swelling, bleeding, the need to take drugs and reducing the functionality of the area involved.

Impressions and scans were made always by the same operator, with the same procedures, to standardize the data acquisition.

The Visual Analog Scale (VAS) was submitted, to the patients of the experimental group A and B and none of them registered pain on this scale, contrary to the control group which recorded post-operative pain in some cases.

Monitoring was carried out as follows:

- Laser surgery

- 1 week
- 8 weeks (T1)
- 16 weeks (T2)

The hypothesis was that palatally impacted canines, after the laser surgery, will suffer a “spontaneous” eruption for reactivation of the physiological eruption, without any orthodontic traction (traditional method). Furthermore, this “spontaneous” eruption was monitored through different digital technology like an intraoral scanner, from the time of the laser surgery to the crown eruption. At this time, we performed the alignment in the arch with direct/indirect bonding technique.

Although, the study analysed the effectiveness of monitoring through the intraoral scanner CS3500 (Carestream Dental), which allows to acquire precise dental coloured impressions.

Digital colour scans were performed in the 1 week, 8 weeks and 16 weeks follow-up visit, through use the intraoral scanner CS3500 (Carestream Dental, USA), which made it possible to obtain scans(accuracy: 30 μm) of the dental arches in .STL format.

4.5.2 Conversion CT to STL model

The examination of the CT allowed to evaluate the three-dimensional morphology of the impacted tooth, its location and inclination in the three planes of space, the depth and the type of inclusion, the relationships with the other elements.

To get an accurate initial situation, the Invesalius 3.1 software was used to export the CT in STL format.

It is an open source software for reconstruction of computed tomography and RM images. The first step is to import CT files, then the range of values, that correspond to the radiopacity of the selected X-ray images that we want to be part of the 3D model, is chosen.

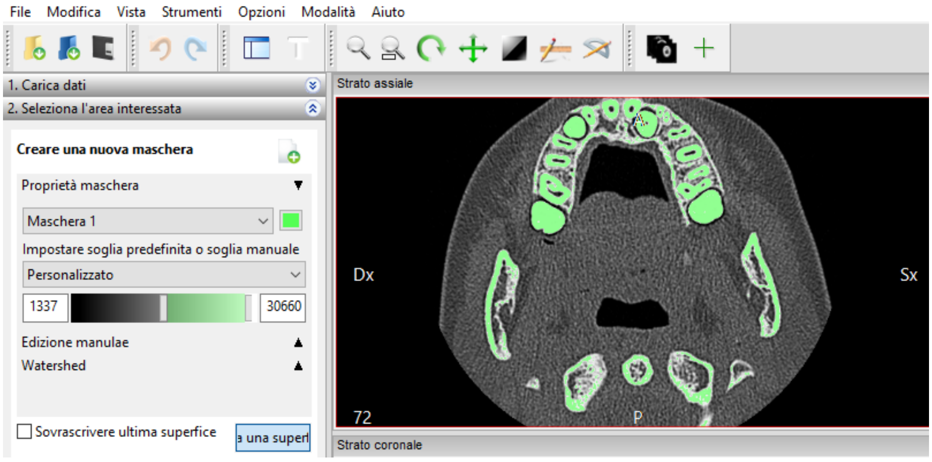


Figure 15 - Range of values is chosen on Invesalius 3.1

At this point a "surface" is generated and a 3D model in STL is obtained, which can be exported and meshed with the STL models of the intraoral scans.

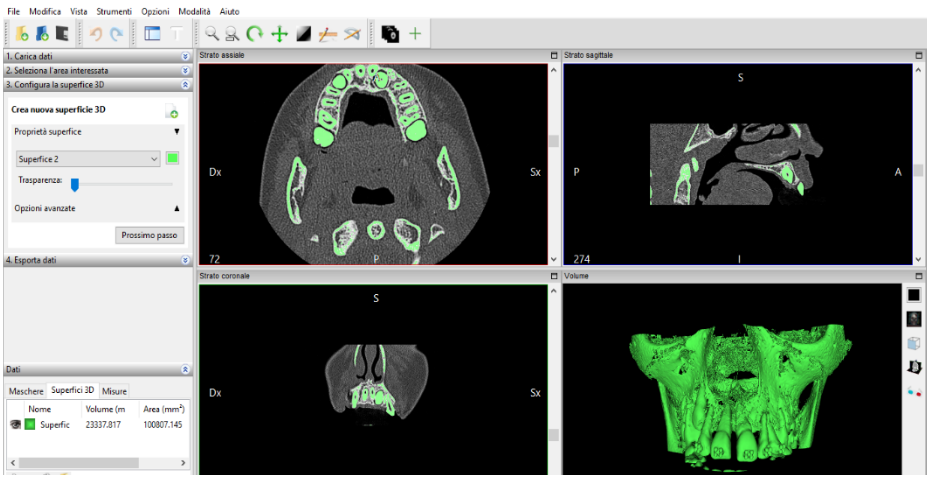


Figure 16- 3D model generated

4.5.3 Overlap of the STL models and measurements

The 3D impressions were imported into the open-source software MeshLab (Visual Computing Lab, Pisa, Italy).

The three-dimensional models of the patients obtained with the scanner at 1 week, 2 months (T1) and 4 months (T2) were superimposed with the 3D models extrapolated from the pre-operative CT (T0).

After importing the scans files, the first operation was 3D data alignment. MeshLab provides a powerful tool for moving the different meshes into a common reference system, able to manage large set of range-maps.

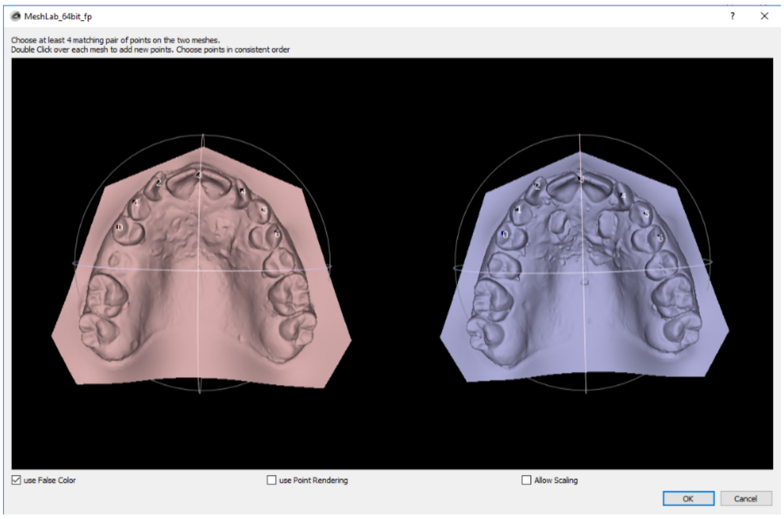


Figure 17- Alignment of two models

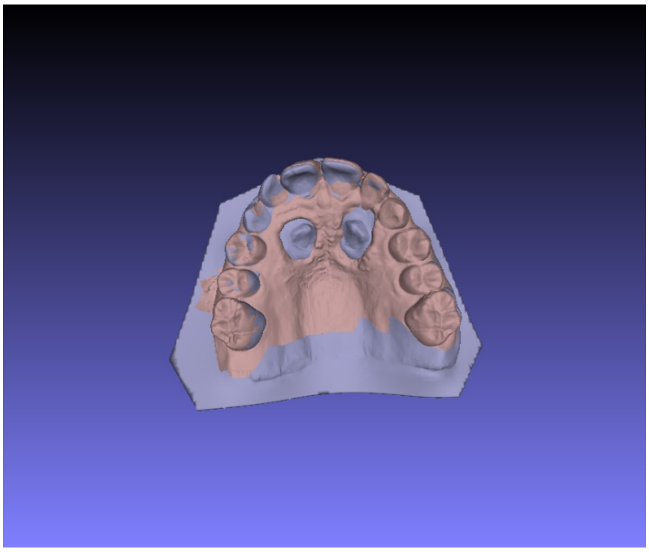


Figure 18- Overlap and alignment of the two models

3D models often need to be re-oriented, or placed in a specific reference system; MeshLab provides a variety of features to manipulate the scale, positioning and orientation of a 3D model, including basic transformation operations like translation/scaling/rotation, automatic re-centering and alignment to axis, geo-referencing with reference points, interactive manipulators for rotation/translation/scaling.

The measurements performed are:

- canine eruption at T1 and T2,
- maximum length of the vestibular surface at T1 and T2,
- maximum length of the palatal surface at T1 and T2,
- distance between canine and central incisor at T1 and T2,
- distance between canine and lateral incisor at T1 and T2.

On the overlapping and aligned 3D models, through the “measuring tool” it was possible to measure millimetrically the distance of these dimensions, and to calculate their changes over time precisely, always taking the same points of reference - i.e. the cusp of the canine and the most apical points of the palatal gingival margins of central and lateral incisor and of the canine itself - both on the palatal and the vestibular surface.

The partial eruptions, obtained from T0 to T1 and from T1 to T2, were measured by superimposing the models and calculating the distances between the initial position of the cusp of the canine and its new position at T1 and T2.

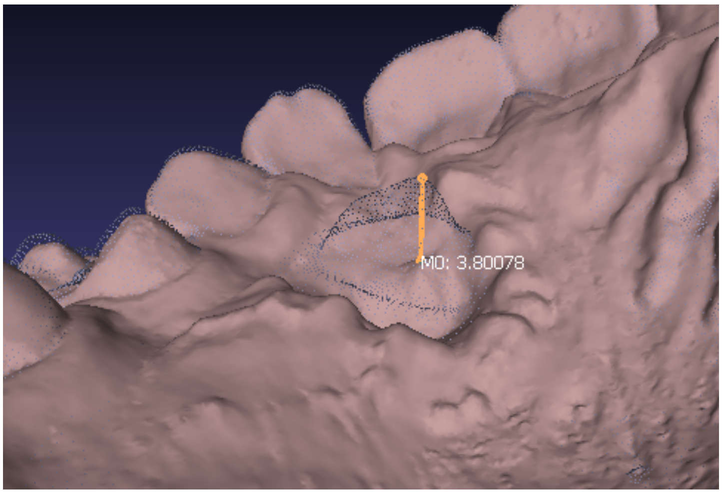


Figure 19- Measuring tool on MeshLab

The maximum eruption of the tooth was measured by calculating the distance in mm between the cusp of the canine on the CT and the cusp at T2, on the superimposed models.

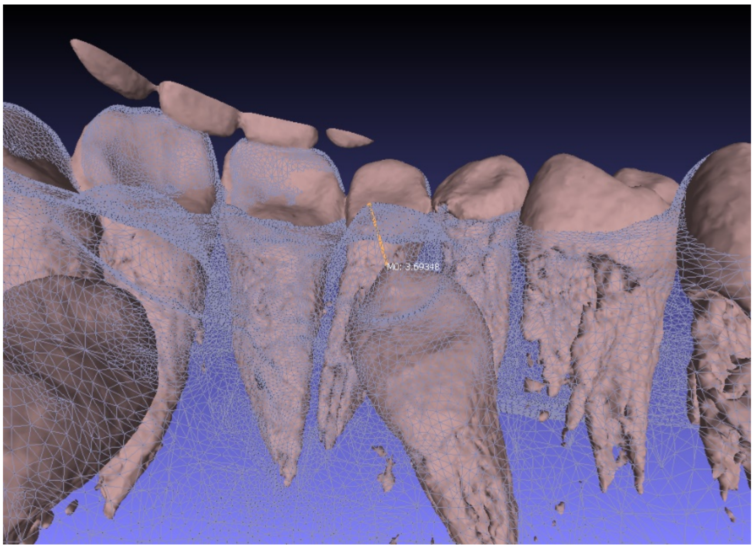


Figure20- Measurement of maximum eruption

The position of the erupting tooth respect to the central and lateral incisors was calculated, measuring the distance, always on superimposed models, of the T1 and T2 cusp with the palatal zenith of both the central incisor and the lateral incisor.

The superimposition of the model at T1 and T2, allowed to always consider the same point on the gingival margin making the measurements accurate and repeatable.

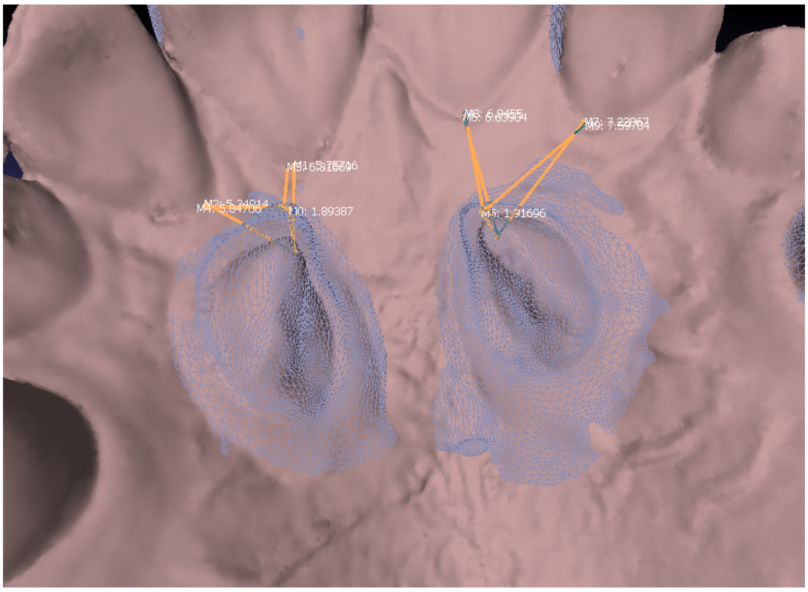


Figure 21- Measurement of the eruption between 2 and 4 months and the distance to the gingival margin of the incisor

The maximum lengths of the palatal and vestibular surfaces of the erupting teeth were measured at T1 and T2, overlapping the models and taking cusps and the most apical point of the vestibular and palatal gingival margin of the canine as reference points.

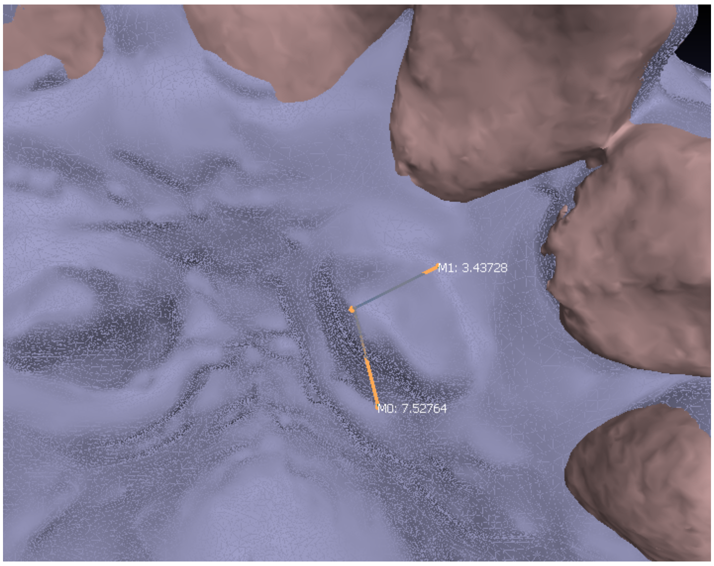


Fig. 22-23 - Measurement of the maximum palatal and vestibular length

4.5.4 Measurement of the areas

IMAGE J is an open source image processing program, designed for scientific multidimensional images. It was possible to obtain the value of the palatal and vestibular areas of the erupting teeth at T1 and T2 by importing 2D images of the surfaces, created with MeshLab, on the program and inserting the maximum length values. The program measures the value of the area of the surface contained in the perimeter, thanks to a pixel-mm conversion.

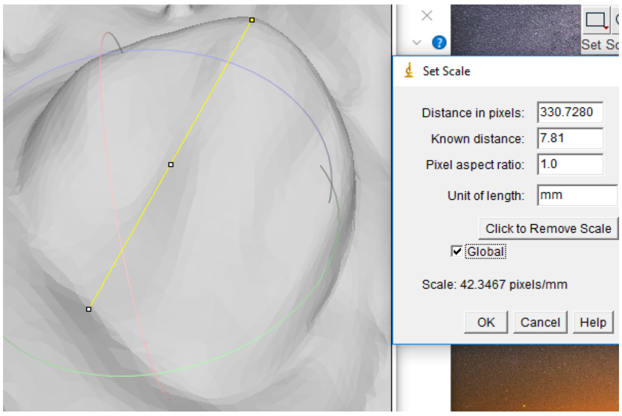


Figure24- Tracing of maximum length of the palatal surface and setting of the scale of conversion

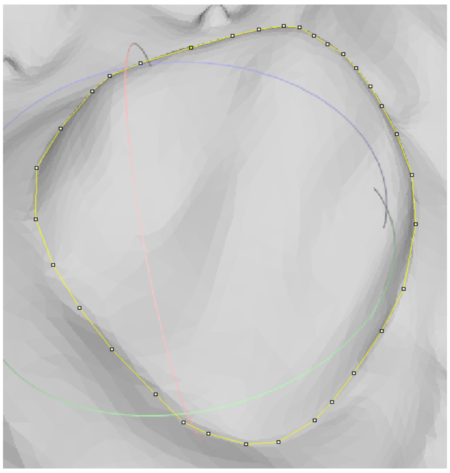


Figure 25 - Tracing of perimeter of the palatal surface

4.5.5 Conventional monitoring

At the same scheduled times, the conventional monitoring was performed. It consists of a clinical evaluation and on the analysis of the plaster casts, obtained by conventional impressions taken at each control visit. The measurements on the plaster casts were performed with a digital caliper (accuracy + 0.03 mm).

Figure 26– Digital Caliper for orthodontics measurements

On the plaster casts, the same measurements that were also realized with digital monitoring allowed to obtain the values of:

- maximum length of the palatal and vestibular surface at T1 and T2,
- distance of the cusp from the zenith of central incisor and lateral incisor at T1 and T2,
- the eruption at T1 and T2 (the eruption cannot be calculated in a realistic way, but only by measuring the approximate height between the cusp and the palatal mucosa).

It was not possible to calculate the data relative to the areas because of the cited analogical techniques. The two monitoring methods were compared by evaluating the difference obtained for each measured data (eruption, distances between canine and incisors and maximum length of vestibular and palatal surface). This comparison allowed to demonstrate the eventually present difference in precision between digital and conventional measurements.

A descriptive and inferential statistical analysis of each data was obtained from both conventional and digital monitoring, determining the statistical averages, the percentage increase and performing the T Student Test for paired data.
The error checking test was performed for all the measurements made, to identify errors in data sets and assess the correctness of information. All the data were measured twice by two observers to establish the error of the methods, the correlations and the mean differences and to compare the validity of the two monitoring methods.

A comparison was made between the values (in millimeters) of spontaneous eruption of the two study groups A and B, by applying the Student's T Test, to determine if the two sets of data were significantly different from each other. The level of significance was set at $p<0,05$.

In addition, the two study groups (A and B) were compared with the control group, evaluating the average eruption times in both groups. The mean value has been calculated.

CHAPTER 5: RESULTS

5.1 Prognosis of the canines

Patient orthopantomograms were carefully evaluated before surgery.

The prognosis of each canine impacted according to the analysis of Ericson and Kurol was evaluated by the OPT.The prognosis can be considered favourable when the angle "α" determined by the major axis of the impacted canine respect to the axis perpendicular to the occlusal plane is equal to or less than 30 ° if mesio-inclined, or 45 ° if it is disto-inclined.

Furthermore, the height of the crown of the canine relative to the roots of the contiguous elements was considered, and the mesio-distal position of the cusp of the canine, which could be located in the four sectors.

The results obtained from each patient are listed in the summary table 1.

Canine	“α”	M-D Position	Height	Prognosis
L	28°	SECTOR I	THIRDMEDIUM	+
L	48°	SECTOR I	THIRD CORONAL	-
R	38°	SECTOR I	THIRD MEDIUM	-
L	21°	SECTOR III	THIRD MEDIUM	+
L	31°	SECTOR IV	THIRD APICAL	-
R	32°	SECTOR III	THIRD MEDIUM	-
L	25°	SECTOR II	THIRD MEDIUM	+
R.	24°	SECTOR II	THIRD MEDIUM	+
L	14°	SECTOR II	THIRD MEDIUM	+
R	37°	SECTOR IV	THIRD MEDIUM	-
L	26°	SECTOR IV	THIRD MEDIUM	+
R	44°	SECTOR IV	THIRD MEDIUM	-
L	49°	SECTOR IV	THIRD MEDIUM	-
R	21°	SECTOR IV	THIRD CORONAL	+
R	42°	SECTOR III	THIRD MEDIUM	-
L	27°	SECTOR III	THIRD MEDIUM	+

R	13°	SECTOR II	THIRDMEDIUM	+
R	26°	SECTOR II	THIRDMEDIUM	+
R	45°	SECTOR II	THIRDMEDIUM	-
L	31°	SECTOR III	THIRDMEDIUM	-
R	44°	SECTOR III	THIRDAPICAL	-
L	52°	SECTOR II	THIRDMEDIUM	-
L	29°	SECTOR IV	THIRDMEDIUM	+
R	32°	SECTOR III	THIRDMEDIUM	-
L	46°	SECTOR II	THIRD APICAL	-
R	30°	SECTOR III	THIRDMEDIUM	-

Table 1

5.2 Eruption

Through the superimposition (with the MeshLab software) of the 3D digital models obtained with the intraoral scanner CS3500, the millimetric values of spontaneous eruptionof the 26 impacted palatally canines treated by laser surgical exposure were obtained.

The table 2 contains all the eruption data calculated for canine in T0-T1 (corresponding to eruption from CT to 8 weeks) and in T1-T2 (from 8 to 16 weeks), and the total eruption movement T0-T2 (at 16 weeks months).

Canine	Eruption T0-T1 (mm)	Eruption T1-T2 (mm)	Total Eruption (mm)
L	3,13	2,21	5,34
L	2,32	1,86	4,18
R	3,34	1,31	4,72
L	3,11	0,82	3,93
L	3,66	2,28	5,94
R	3,13	1,81	4,95
L	2,21	1,48	3,69
R	2,84	1,89	4,74
L	2,33	1,92	4,25

R	4,26	1,91	6,17
L	1,44	1,68	3,12
R	1,29	1,43	2,72
L	1,78	1,55	3,33
R	4,71	1,83	6,54
R	1,03	2,72	3,75
L	2,66	2,14	4,80
R	2,31	3,42	5,73
R	3,54	1,88	5,42
R	3,61	2,69	6,3
L	3,23	2,68	5,91
R	3,03	1,82	4,85
L	3,41	1,97	5,38
L	3,28	2,45	5,73
R	4,02	3,02	7,04
L	4,12	2,78	6,9
R	2,81	2,02	4,83

Table 2

The average eruption values were also calculated in each time interval.

$$Average\ eruption\ 0 - T1 = \frac{\sum eruptions\ \ T1}{N}$$

$$Average\ eruption\ T1 - T2 = \frac{\sum(eruption\ \ T2 - eruption\ T1)}{N}$$

$$Average\ Total\ eruption = \frac{\sum eruptions\ \ T2}{N}$$

With N=26

The results are:

- The average eruption in 0-T1 = 2,95 mm
- The average eruption in T1-T2 = 2,06 mm
- The average total eruption = 5.01 mm

5.3Comparison between the effect of the CO_2 and Diode laser

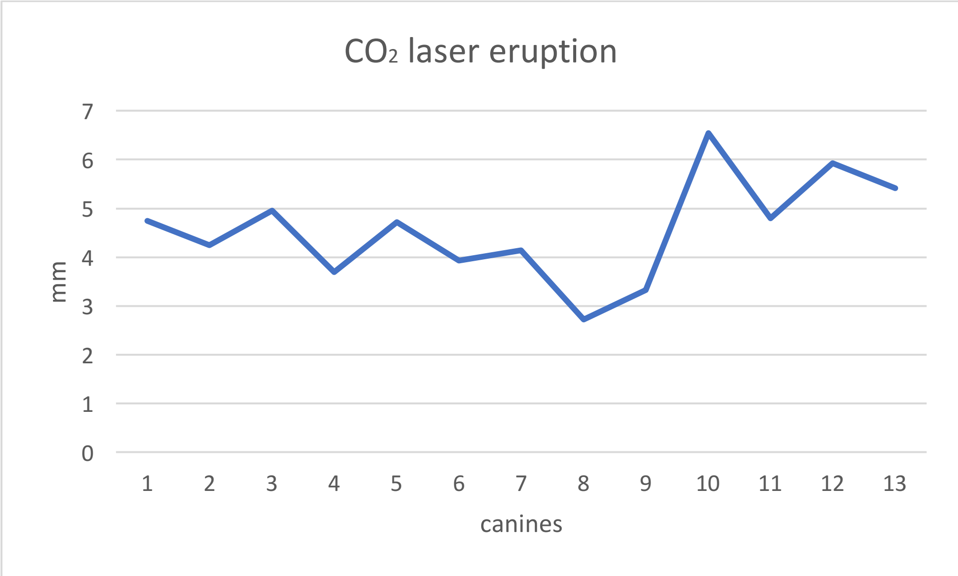
Within the 26 canines that were surgically exposed by laser operculectomy, the two study groups A and B, treated with the CO_2 laser and the Diode laser respectively, were compared.

For group A (n= 13 impacted palatally canines treated by CO_2 laser) and group B (n= 13 impacted palatally canines treated by diode laser) the measurement of the eruption path (in millimeters) of the tooth performed over sixteen weeks gave the following results:

CO_2 LASER

1	4,74
2	4,25
3	4,95
4	3,69
5	4,72
6	3,93
7	4,14
8	2,72
9	3,33
10	6,54
11	4,8
12	5,93
13	5,42
Mean	**4,55**

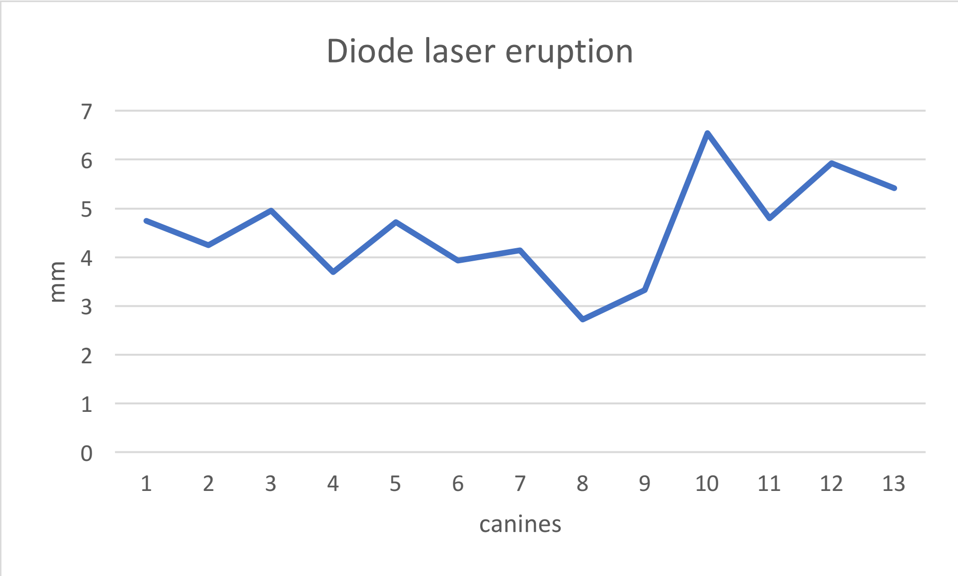
Table 3



DIODE LASER

1	5,94
2	3,75
3	6,17
4	3,12
5	5,34
6	4,18
7	7,04
8	6,9
9	6,3
10	5,91
11	4,85
12	5,38
13	4,83
Mean	***5,36***

Table 4



Student's T Test

To compare the two averages of the results obtained with the two different types of lasers, the t-test (also called Student's T-Test) was applied.

	CO_2 Laser	Diode Laser
Sampling number	13	13
Mean	4,55	5,36
Standard deviation (SD)	1,0049	1,140

T	0,0471
Degrees of freedom	24
P (significance level)	0,7280

Table 5

A significance level of α = 0,05 was chosen.

The degrees of freedom correspond to d.f. = N - 2 = (13 + 13) - 2 = 24, where N corresponds to the sum of the subjects belonging to the two samples N = n (group A) + n (group B).

The difference between the observed means of the two groups is not significant for $p < 0.05$, so it is not attributable to the different action of the two different types of lasers but is to be considered accidental.

5.4 Comparison between the Study groups and the Control group

The comparison is based on the eruption timing of the canines in the two groups analyzed: the mean time of spontaneous eruption of canines in the study group (groups A and B; n = 26 canines disincluded by laser surgery) was compared with the mean time of the orthodontic traction performed in the control group (n = 13 canines treated by the conventional surgical-orthodontics approach).

With reference to the study group, on the 26 canines treated by laser surgical exposure and without the application of any orthodontic traction device, it was possible to programme and apply the orthodontic multi-brackets treatment to align the tooth in the arch after 4 months (16 weeks) from the surgery.

Therefore, the average eruption time from the surgical exposure to the moment in which an orthodontic anchoring means (bracket or button) could be applied to the crown of the canine to align the tooth in the dental arch was 4 months.

In the control group, the time was calculated when each canine exposed its crown in order to be aligned in the arch with multibrackets technique.

The values obtained are as follows:

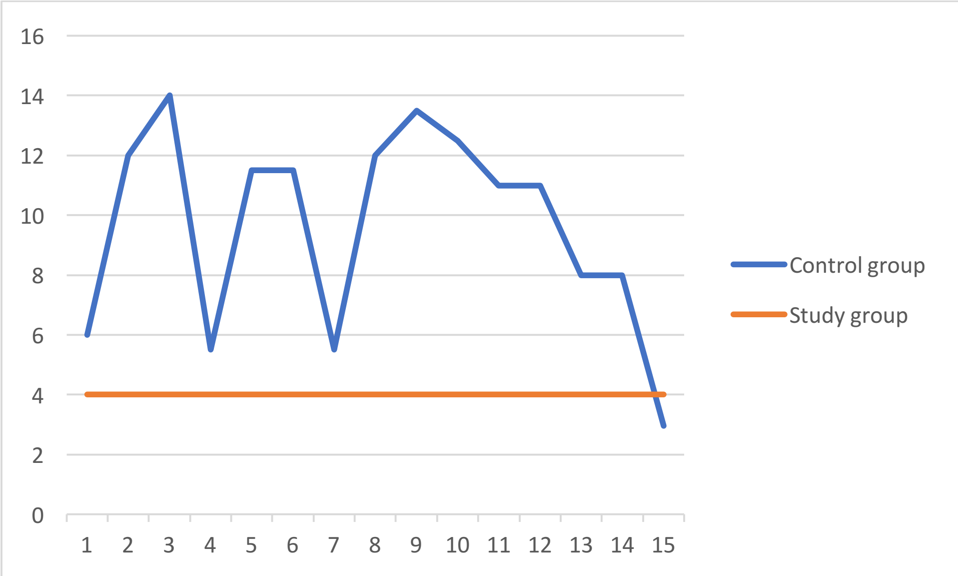
	Orthodontic traction time *(months)*
1	6
2	12
3	14
4	5,5
5	11,5
6	11,5
7	5,5
8	12
9	13,5
10	12,5
11	11
12	11
13	8
Mean	**10,03**
SD	**2,95**

Table 6

The duration of the orthodontic traction varied from 5.5 months to 14 months (mean value: 10.03 months; SD: 2.95).

	Eruption time
Study group (A+B)	4 months
Control group	10 months

Table 7



Graphic 1The two average times obtained in the study group and in the control group

5.5 Speed of eruption

Starting from the eruption data, calculations included: the average speeds in the interval 0 – 2 months, 2 months – 4 months, and 0 – 4 months. Considering 0 as the value obtained from the STL model from the CT.

The speeds in mm/day in every ranges of time were found with the following formula:

$$Speed = \frac{eruption\, Tf - eruption\, Ti}{Tf - Ti}$$

With Tf = final time of the interval and Ti = initial time of the interval

Canine	Speed 0-T1	Speed T1-T2	Speed 0-T2
L	0,052	0,037	0,045
L	0,039	0,031	0,035
R	0,056	0,022	0,039
L	0,052	0,014	0,033
L	0,061	0,038	0,050

R	0,052	0,030	0,041
L	0,037	0,025	0,031
R	0,047	0,032	0,039
L	0,039	0,033	0,035
R	0,071	0,032	0,051
L	0,024	0,028	0,026
R	0,022	0,024	0,023
L	0,030	0,026	0,028
R	0,079	0,030	0,054
R	0,017	0,045	0,031
L	0,044333	0,035667	0,04
R	0,0385	0,057	0,04775
R	0,059	0,031333	0,045167
R	0,060167	0,044833	0,0525
L	0,053833	0,044667	0,04925
R	0,0505	0,030333	0,040417
L	0,056833	0,032833	0,044833
L	0,054667	0,040833	0,04775
R	0,067	0,050333	0,058667
L	0,068667	0,046333	0,0575
R	0,046833	0,033667	0,04025

Table 8

The average speed in 0-T1 is: 0,049mm/day

The average speed in T1-T2 is: 0,034mm/day

The average total speed is: 0,042 mm/day

5.6 Proximity to central and lateral incisive

The table shows the distances between the cusp of the canines and the apical point of the gingival margins of the central and lateral incisors at T1 (2 months) and T2 (4 months).

Table 9

Canine	D Cusp-Zenith of Central Incisor T1 (mm)	D Cusp-Zenith of Lateral Incisor T1 (mm)	D Cusp-Zenith of Central Incisor T2 (mm)	D Cusp-Zenith of Lateral Incisor T2 (mm)
L	5,84	4,38	5,43	5,75
L	4,58	4,26	3,48	5,27
R	3,86	7,76	4,59	6,82
L	6,55	2,98	5,98	2,79
L	7,45	8,08	7,86	8,75
R	7,34	7,24	7,52	8,05
L	7,24	3,91	7,62	5,05
R	5,75	5,34	6,21	5,74
L	6,64	7,22	6,95	7,59
R	3,98	6,29	5,06	6,86
L	6,05	3,34	6,98	4,29
R	5,80	7,47	4,12	6,52
L	5,92	5,48	4,85	4,51
R	4,81	5,26	6,64	5,87
R	8,61	6,42	7,33	5,79
L	6,56	3,89	4,76	4,14
R	8,96	6,28	8,51	6,03
R	9,38	4,37	9,27	4,31
R	5.61	6,69	6,05	6,79
L	6.72	6,26	6,99	6,67
R	6,45	4,22	5,52	3,94
L	7,14	7,12	6,39	7,71
L	11,17	4,63	10,68	4,02
R	11.34	7.04	11.54	6.21
L	7.82	7.19	7.70	7.16
R	5,71	3,52	5,96	3,80

The differences between the distances at 4 and 2 months were calculated to evaluate the approach of canines at the central and lateral incisor during the eruption. It emerged that in two patients the canine approached the lateral incisor, in four cases it approached the central, in eight cases it approached both. We verified that it was due to the inclination of the tooth, evaluating the initial inclination of the canine from the CT; in this way, we excluded the possibility that this approach was due to the laser application.

5.7 Palatal and Vestibular area of the canines

The maximum length of the palatal and vestibular surfaces at 2 and 4 months are reported in the following table.

Lenght Vest T1	Lenght Pal T1	Lenght Vest T2	Lenght Vest T2
1,65	4,31	2,949	6,04
2,04	4,59	3,036	7,41
1,388	6,824	1,79	7,23
1,842	6,481	2,11	7,18
2,82	7,91	3,82	7,63
1,61	3,614	1,87	6,24
2,259	7,091	3,437	7,53
3,51	6,643	5,18	7,847
2,973	6,065	4,799	7,604
2,013	4,532	2,426	7,811
2,23	4,21	2,724	6,783
1,12	3,016	3,247	2,7
0,95	0,35	3,936	2,54
3,228	3,993	4,239	4,808
2,329	3,753	2,457	6,726
2.26	6.80	3,1	7,46
1,02	1,75	2,75	5,53
0,71	1,03	2,8	5,42
1,05	2,09	1,68	3,53
2,73	7,38	4,41	8,03
1,04	5,9	2,88	7,07
1,03	3,02	2,62	4,74
2,73	3,4	4,02	5,12
2,52	3,71	3,87	4,98
2,13	4,78	2,91	6,59
2,02	4,34	2,38	6,58

Table 10

The vestibular and palatal areas were calculated, thanks to IMAGEJ, at T1 (2 months) and T2 (4 months).

We found the differences between the size of the areas at 2 and 4 months and their percentage increase:

$$Increase\ \% = \frac{Area\ T2 - Area\ T1}{Area\ T2}\ x\ 100$$

With Area T2= Area at 4 months and Area T1= Area at 2 months

We calculated the average area of the vestibular and palatal surface exposed to 2 months and 4 months as:

$$Average\ Area\ (T1) = \frac{\sum_{i=1}^{N} Area\ T1}{N}$$

With: N= 26 and Area T1= Area at 2 Months

$$Average\ Area\ (T2) = \frac{\sum_{i=1}^{N} Area\ T2}{N}$$

With: N= 26 and Area T2= Area at 4 Months

We calculated the average percentage increase as:

$$Average\ increase\ \% = \frac{\sum_{i=1}^{N} Increase\ \%}{N}$$

With: N= 26.

The results are:

- The average palatal area at 2 months = 22,67 mm^2
- The average palatal area at 4 months = 33,91 mm^2
- The average percentage increase of the palatal area = 39,09%

- The average vestibular area at 2 months = 11,44 mm^2
- The average vestibular area at 4 months = 20,31 mm^2
- The average percentage increase of the vestibular area = 41,82%

5.8 Conventional vs Digital monitoring

The following table shows the differences between analogical and digital measurements.

The table 5.8 shows the differences (in mm) between casts and STL models on the measurement of the eruption at T1 and T2.

Canine	D eruption T1	D eruption in T2
1	0,63	1,34
2	0,32	1,18
3	0,34	1,15
4	0,11	0,93
5	0,66	1,44
6	0,13	0,94
7	0,21	1,19
8	0,34	1,23
9	0,33	1,25
10	0,76	1,67
11	0,06	0,12
12	0,29	0,72
13	0,28	0,83
14	0,21	1,54
15	0,03	0,75
16	0,16	0,88
17	0,31	0,73
18	0,22	0,32
19	0,56	0,8
20	0,23	0,71
21	0,33	0,35
22	0,41	0,28
23	0,58	0,73
24	0,33	0,64
25	0,12	0,9

26	0,61	0,53

Table 11

The average difference of the total eruption (in T2) is: 0,91 mm.

The table 5.9 shows the differences (in mm) between casts and STL models in the measurement of the distance to incisor at T1 and T2.

Canine	Diff cusp-zenith central incisor T1	Diffcusp-zenith lateral incisor T1	Diffcusp-zenith central incisor T2	Diffcusp-zenith lateral incisor T2
1	0,05	0,08	0,36	0,25
2	0,34	0,24	0,52	0,05
3	0,24	0,09	0,12	0,05
4	0,14	0,26	0,41	0,32
5	0,05	0,02	0,02	0,29
6	0,31	0,26	0,36	0,37
7	0,25	0,16	0,21	0,24
8	0,14	0,22	0,05	0,09
9	0,02	0,21	0,06	0,36
10	0,05	0,34	0,98	0,29
11	0,11	0,08	0,17	0,21
12	0,20	0,03	0,12	0,02
13	0,08	0,02	0,15	0,01
14	0,16	0,38	0,07	0,25
15	0,42	0,26	0,52	0,00
16	0,16	0,19	0,26	0,14
17	0,46	0,28	0,11	0,03
18	0,18	0,17	0,27	0,31
19	0,11	0,19	0,05	0,29
20	0,22	0,26	0,49	0,67
21	0,05	0,22	0,52	0,44
22	0,14	0,12	0,39	0,41
23	0,17	0,13	0,18	0,02

24	0,34	0,04	0,14	0,21
25	0,32	0,19	0,70	0,16
26	0,21	0,02	0,46	0,30

Table 12

The average difference of the distance between the cusp and the incisor is: 0,22 mm.

The table 5.10 shows the differences (mm) between casts and STL models on the measurement of the vestibular and palatal length at T1 and T2.

Canine	Diff L. vest T1	Diff L. pal T1	Diff L. vest T2	Diff L. pal T2
1	0,15	0,31	0,051	0,04
2	0,04	0,09	0,036	0,09
3	0,12	0,18	0,29	0,23
4	0,16	0,02	0,11	0,18
5	0,18	0,09	0,32	0,13
6	0,11	0,12	0,37	0,24
7	0,26	0,59	0,063	0,03
8	0,79	0,14	0,18	0,15
9	0,47	0,07	0,299	0,11
10	0,013	0,032	0,074	0,189
11	0,23	0,21	0,224	0,183
12	0,12	0,016	0,247	0,3
13	0,45	0,35	0,064	0,04
14	0,228	0,007	0,239	0,308
15	0,171	0,253	0,043	0,226
16	0,26	0,30	0,1	0,46
17	0,02	0,25	0,35	0,53
18	0,21	0,33	0,8	0,42
19	0,05	0,09	0,18	0,03
20	0,23	0,38	0,41	0,43
21	0,54	0,4	0,38	0,07
22	0,03	0,02	0,62	0,24
23	0,73	0,4	0,02	0,12

24	0,02	0,21	0,37	0,48
25	0,13	0,78	0,41	0,29
26	0,52	0,34	0,38	0,58

Table 13

The average difference of the length of the areas is: 0,24 mm

Student's T test was applied for paired data of the total eruption, fixing the p-value <0,05, and obtaining statistically significant values (3,25746E-08). The interpretation of these results translates into a discrepancy between the two methods of measurement and a greater accuracy in monitoring with digital technologies compared to the conventional method.
All the data were measured by two different operators to determine the method error of digital and analogical measurements. For each compared data, the correlation coefficient, the relative and absolute errors, and the mean differences were calculated. (Table 8)

Measurement Method	Correlation coefficent	Error of method	Mean difference
Digital	0,994-0,999	0,20-0,99%	0,17-0,87%
Analogical	0,937-0,994	2,28-4,05%	1,00-7,12%

Table 14 – Range of correlation, error (%) and mean difference (%) values of the two measurement methods compared

A coefficient of correlation close to 1 indicates a “positive” and “strong” relationship between the two examined variables. In other words, increasing one variable, the other one will increase too. In this case, in particular, it is observed a mean coefficient of correlation higher for digital measurements (0,9965) than the analogical ones performed with caliber (0,9665). This indicates a stronger correlation between the data of the digital method, suggesting a less dependence on who makes the measurement itself, i.e. it is independent of the operator. This result is also supported by the absolute error values and the mean differences which are both in favour of the digital method with mean values of 0,695% and 0,520% respectively, against 3,165% and 4,060% of the analogical one.

CLINICAL CASES

1. Group A – CO_2 Laser

Case n.1

F.F., male, 13, was sent to our department by a private dentist, with the diagnosis of impacted palatally canines. At the time of our first visit, the patient presented a Orthopantomogram (OPG).

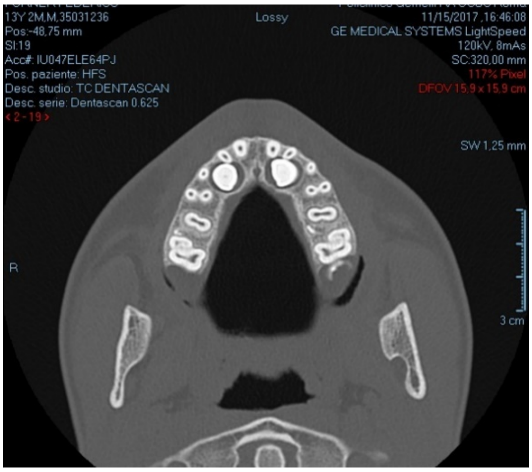
Rx OPT

The family history and the medical and dental pathological anamnesis, the extra-oral and intra-oral examination were collected, and the panoramic radiograph was evaluated. There was a positive familiarity with the impaction of the canine.

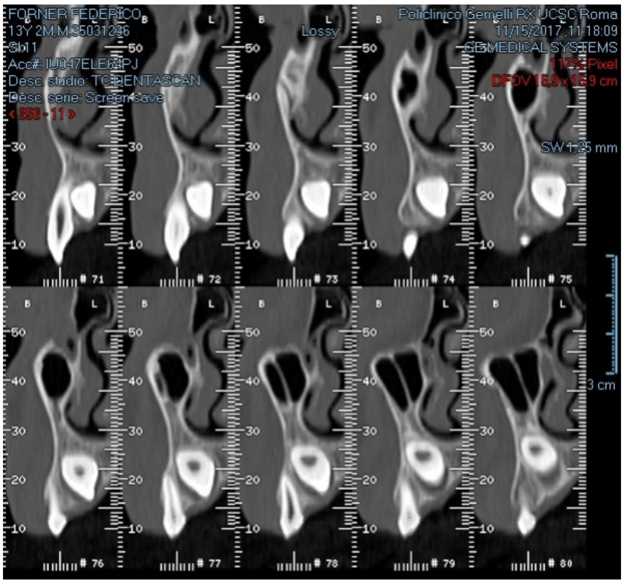
The young patient is in good general health, does not present dental and skeletal anomalies and is a collaborating patient. Therefore, it respects the inclusion criteria of our study and can be treated by laser surgery.

The patient presented the deciduous canines in the arch, already a first sign of the impaction of the corresponding permanent ones. At palpation the "canine bulges" were palpable on the palatal side. This semeiological aspect confirmed the diagnosis of impacted palatally canine.

A second level x-ray examination, a Cone Beam CT and blood tests were prescribed to evaluate the possibility of appropriate treatment.



CBCT



CBCT

The surgery exposure has been planned, after the patient's consent has been visualized and signed.

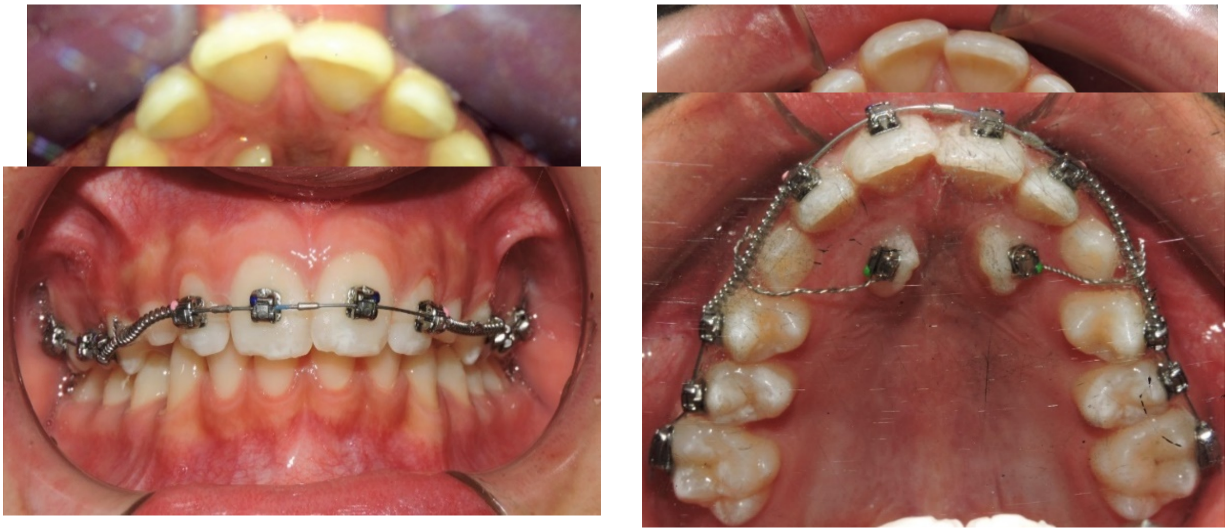
The canine was in a superficial position, covered only by mucosa. The opercolectomy to expose the dental crown was performed using the CO_2 laser.

The first check 1 week after the operation shows the visible cusps of the palate and the healing tissues. The 2-month check shows the well-healed pericoronal tissues.

The 4-month control shows the crown of the canines clearly visible on the palate, a condition that allows the application of an anchoring means and the start of alignment of the tooth in the dental arch using the Damon System.

Figure - 1 week after surgery

Figures 2-3: 8 weeks after surgery (left) and 16 weeks after surgery (right)



Figures 4-5:- Fixed appliances (Damon System)

Case n.2

E.V., male, 14. The patient had bilateral inclusion of the upper canines, placed deep in the palatal bone.

There was no familiarity with impacted canines or other dental abnormalities.He did not undergo previous therapy and had a good general health.

The deciduous canines were still present in the arch.

The canine was in a deep position, covered by bone and mucosa.

The opercolectomy was performed using the CO_2 laser and the ostectomy to expose the dental crown was performed through a handpiece at low speed and under abundant irrigation, with a rosette bur.

Figures 1-2: Before surgery (left) and 1-week post-surgery

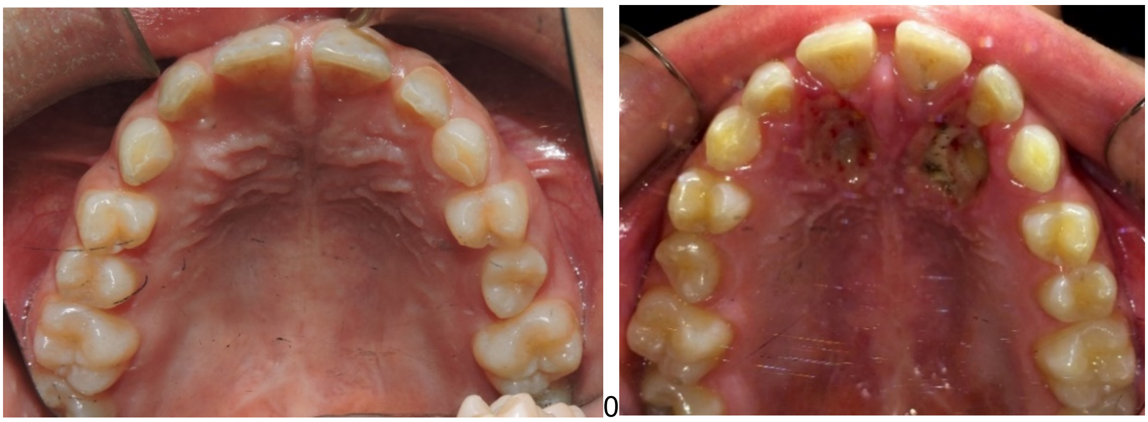
Figure 3: 8 weeks post-surgery

Figure 4: 16 weeks post-surgery

Case n.3

C.M., female, 19 . On intra-oral examination it was noted the persistence of the deciduous in the dental arch. In addition the presence of a dentoalveolar discrepancy with anterior diastemas.

The Rx OPT and CBCT reveals the impaction of the two upper canines in the palatal site. The canines appear completely covered by the bone.



Figures 1-2 : Before surgery (left) and 1-week post-surgery


Figure 3: 8 weeks post-surgery

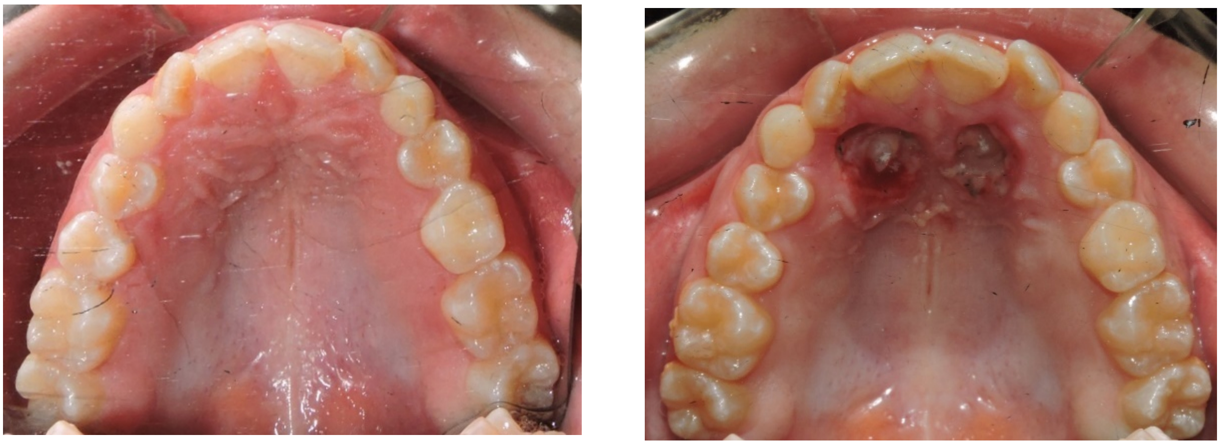

Figure 4: 16 weeks post-surgery

Case n.4

L.A., female, 17. The patient had a palatal inclusion of the two maxillary canines. She had not undergone previous therapy and had good general health.

The intra-oral examination shows the presence of the deciduous in the arch, and a medium oral hygiene. A dental crowding in the upper arch was also appreciated.

CBCT shows that the right canine was near to the lateral incisor root. The impacted canines were both in a deep position.



Figures 1-2: Before laser exposure (left) and 1 week after laser exposure (right)

Figure 3-4: 8 weeks after laser exposure (left) and 16 weeks after the surgery (right)

Case n.5

O.M., female, 13.

The patient presented a monolateral superficial inclusion of the upper left canine with the persistence of the omolateral deciduous.

At palpation, the "canine bulge" was palpable on the palatal left side. This semeiological aspect confirmed the diagnosis of impacted palatal canine.
The teeth in the arch were well aligned and no other orthodontic problems were present.

The CBCT confirms the mucosal inclusion of the left canine.

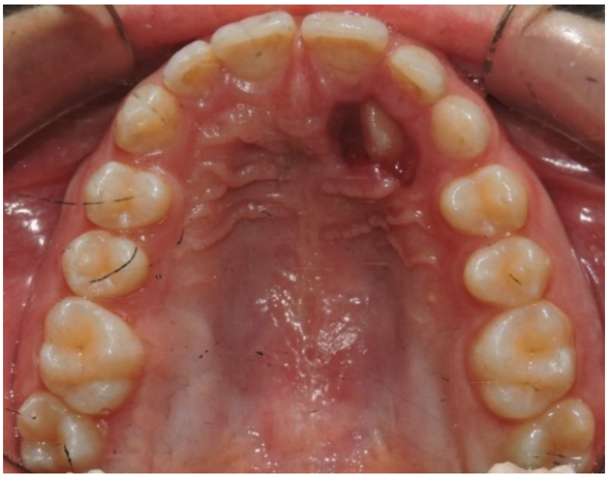


Figure 1: 1week post-surgery

Figure 2: 8 weeks after laser exposure

Figure 3: 16 weeks after laser exposure

Case n.6

D.D, male, 15.

The patient had the upper left canine impacted in the palatal side. The left deciduous canine was absent in the dental arch and the space was closed by the lateral and the first premolar.
As can be seen from the intraoral photographs, the sliding of all the teeth to the left were responsible for a deviation of the upper midline.
Furthermore, there is a severe dental crowding, so the decision to recover the 2.3 and extract the 1.4.

The CBCT showed the deep bone impaction of the left canine.

Figure 1:Pre surgery

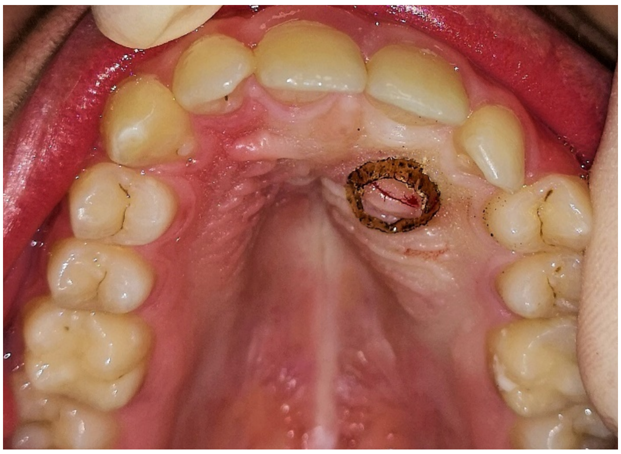


Figure 2: CO_2 laser surgery

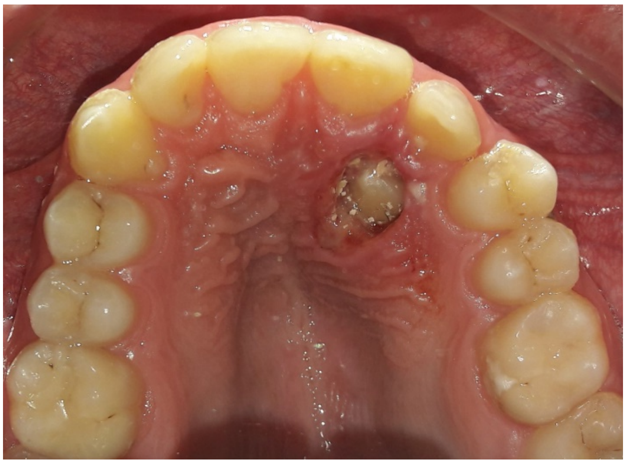


Figure3: 1 week post-surgery

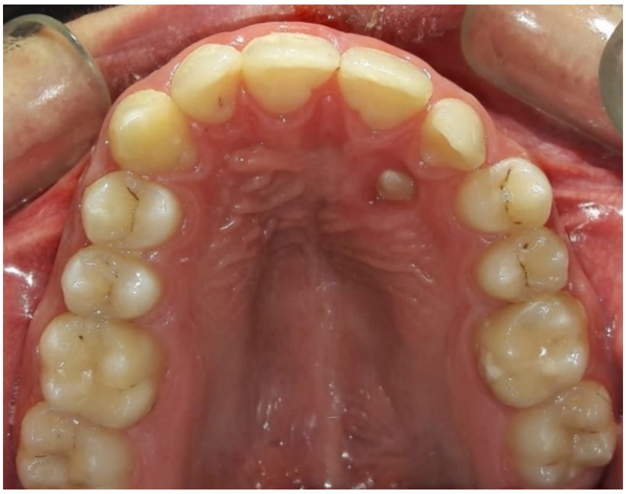


Figure 4: 8 weeks post-surgery

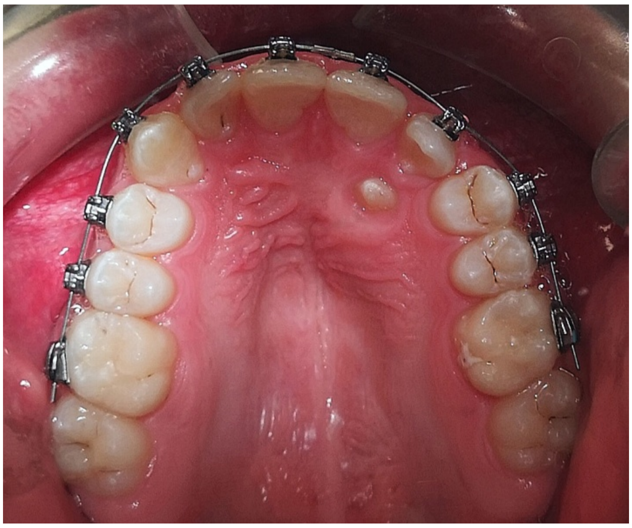


Figure 4: 16 weeks after surgery, fixed therapy application

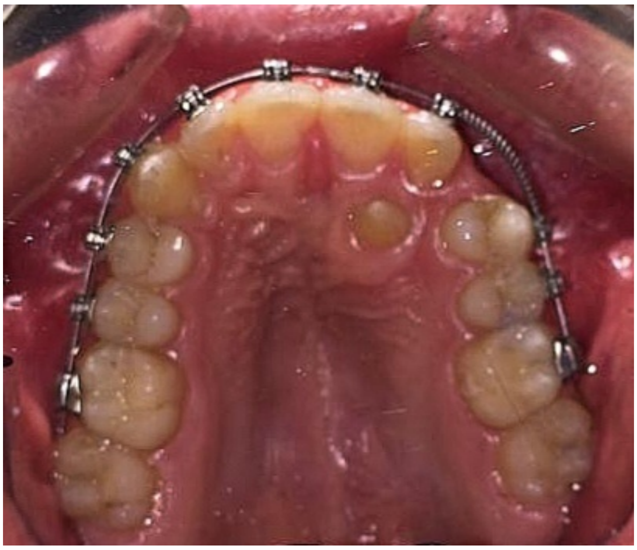
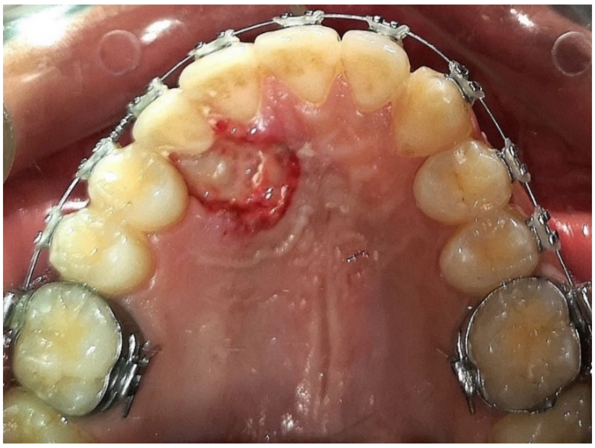


Figure 5: 6 months after laser surgery

Case n.7

A.T., male, 18. The patient's first visit with OPT and CBCT showed a palatal inclusion of the upper right canine in the palatal bone, but with a positive inclination (angle α: 10°).

He was undergoing orthodontic treatment because there were several problems including severe crowding in the upper and lower arch. The deciduous canine was absent in the dental arch and the space was closed by the lateral and the first premolar. As can be seen from the intraoral photographs, the sliding of all the teeth caused a deviation of the upper midline. The therapy involved the extraction of the first premolars and the disinclusion of the right canine with a diode laser.



Figures 1-2: Before laser exposure (left) and 1 week after laser exposure (right)

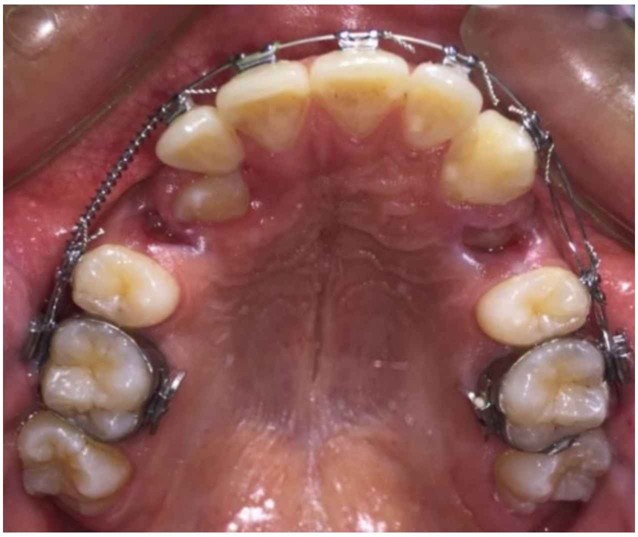


Figure 3: 8 weeks post-surgery

Figure 4: 16 weeks after surgery

Case n. 8

B.E., 15, male.

The patient had already undergone a previous orthodontic fixed treatment in a private structure and presented, therefore, brackets on the upper dental arch. The fixed therapy was interrupted and restarted at 4 months post-surgery.

The right deciduous canine persisted in the arch and the left canine was in the eruption phase. At palpation, the "canine bulge" was palpable on the palatal right side.

The Rx OPT and CBCT confirmed the unilateral inclusion of the upper right canine in the palatal mucosa.

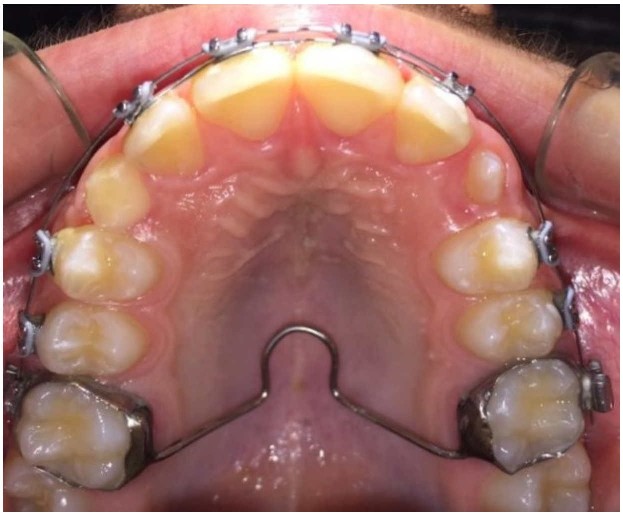


Figure 1: Before laser exposure

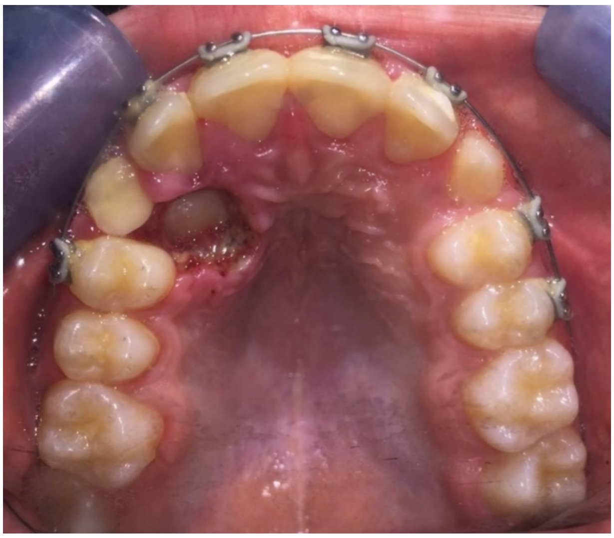


Figure 2: 1 week after laser exposure

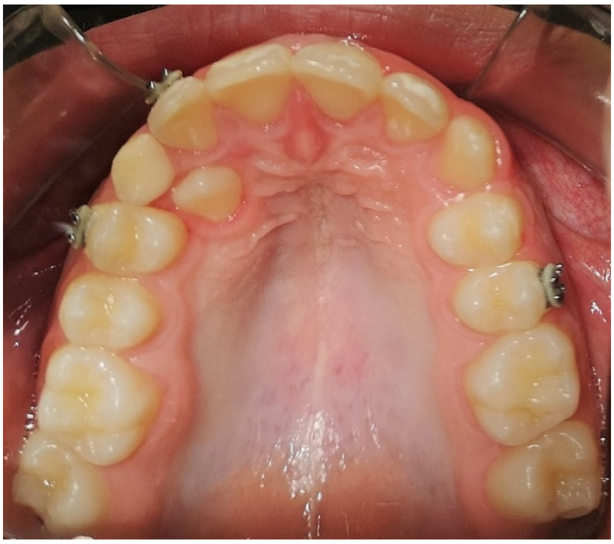


Figure 3: 8 weeks post-surgery

Figure 4: 16 weeks after surgery

Case n.9

I.D. male, 13.

The patient had the upper left canine impacted in the palatal side, near the crest. The left deciduous canine was absent in the dental arch, and the right permanent canine had erupted. As can be seen from the intraoral photographs, the sliding of the teeth caused a deviation of the upper midline.

He was undergoing an orthodontic fixed treatment on the upper dental arch, and an open coil created the space for the permanent canine.

The CBCT showed the deep bone impaction of the left canine.

Figure 1: 1 week after laser exposure

Figures 2-3: 8 weeks post-surgery (left), 16 weeks after surgery (right)

2. Group B – Diode Laser

Case n. 10

C.S., male, 16. The patient presented a unilateral inclusion of the upper right canine. The deciduous canines persisted in the dental arch.

From the three-dimensional CBCT radiographic examination, it was seen that the inclusion was deep within the palatal bone. The oral hygiene was good, and the patient was collaborating. He had familiarity for impacted tooth.

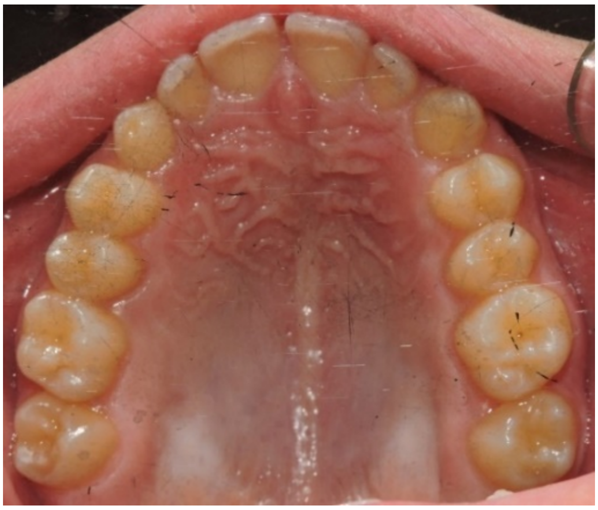


Figure 1: Pre-surgery

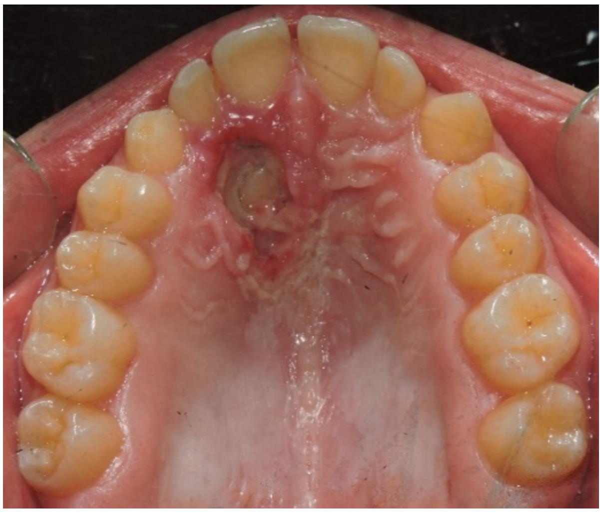


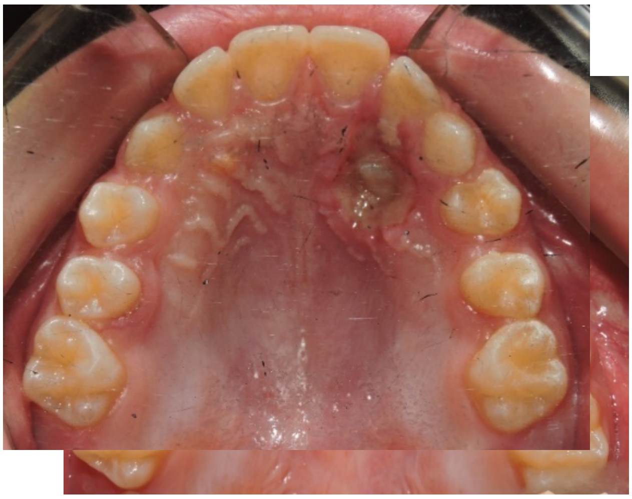
Figure 2: 1-week post-surgery

Figure 3: 16 weeks post-surgery

Case n.11

V.J., female, The young patient presented the upper left canine impacted in the palate. The patient had a II Class dental malocclusion with deep bite. She had not undergone previous orthodontic therapy.

CBCT showed the deep bone inclusion of the canine, and the proximity to the root of the lateral incisor.



Figures 1-2: Pre-surgery (left) and 1-week post-surgery (right)

Figures 3-4: 8 weeks (left) and 16 weeks (right) post-surgery

Figures 5: Fixed appliances (Damon System)

Case n. 12

F.L., male, 13 . The patient had the upper canines deeply impacted in the bone of the palate.

The intraoral examination showed the persistence of the left deciduous in the dental arch, and the absence of the left deciduous canine, with a visible resorption of the bone crest in the canine site.

The patient had not undergone previous therapy and had a good oral hygiene and a good general health.

Figure 1-2 Before surgery (left) and 1 week after laser surgery

Figures 3-4 :8 weeks (left) and 16 weeks after surgery (right)

Case n.13

A.AM, female, 12. The patient presented the upper right canine impacted in the palatal side and had familiarity for upper canine impaction.

The young patient had already undergone a previous orthodontic fixed treatment in a private structure and presented, therefore, brackets on the upper dental arch.

The right deciduous canine persisted in the arch and the left canine was absent.

The CBCT showed the mucosal impaction of the right canine. The element 2.3 was in the eruption phase.

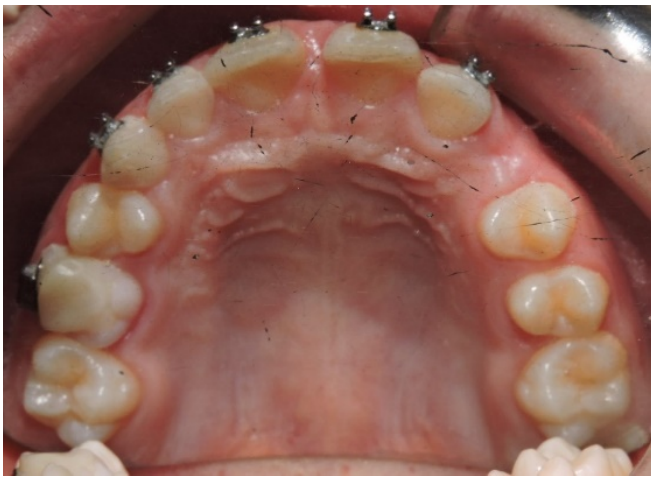


Figure 1: Pre-surgery

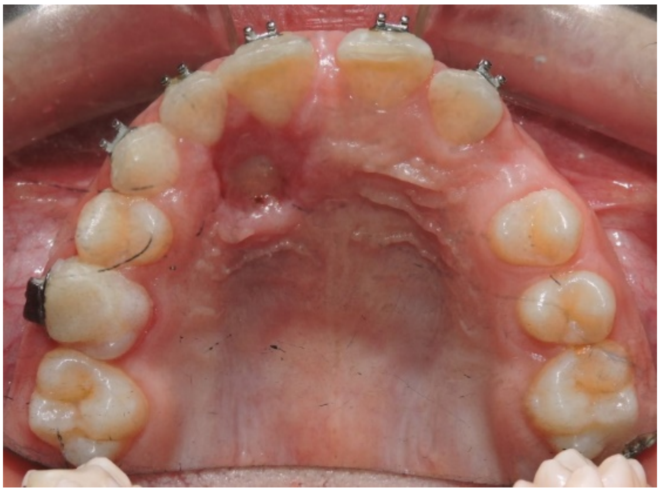


Figure 2 : 1-week post-surgery (right)

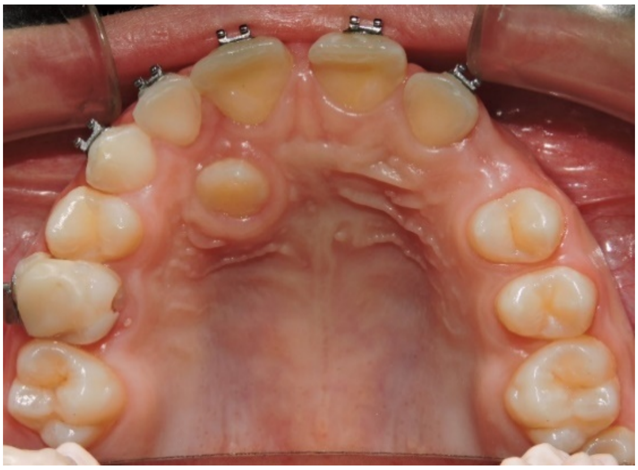


Figure 3: 16 weeks after laser exposure

Case n.14

A.E., male, 17. The patient presented a superficial impaction of the maxillary canines on the palatal side and had familiarity for upper canine impaction.

The intraoral examination showed the persistence of the right deciduous canine and at palpation, the “canine bulge” was palpable on the palatal right side. This semeiological aspect confirmed the diagnosis of impacted palatal canine.

The patient had a II class deep bite malocclusion and had not undergone previous orthodontic therapy.

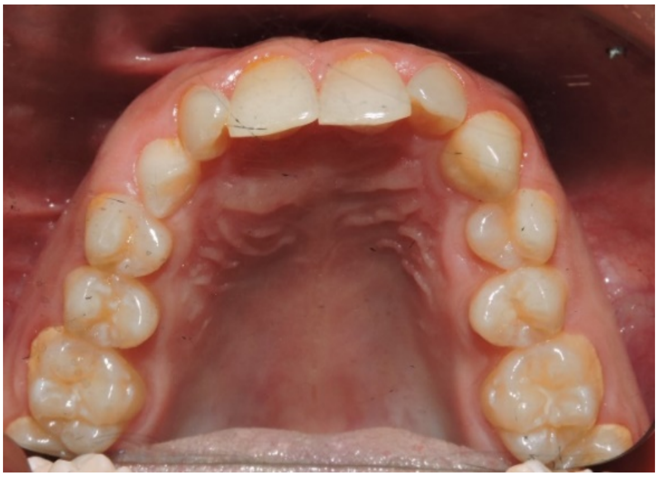


Figure 1 - Pre-surgery

Figure 2 : 1 week after surgery

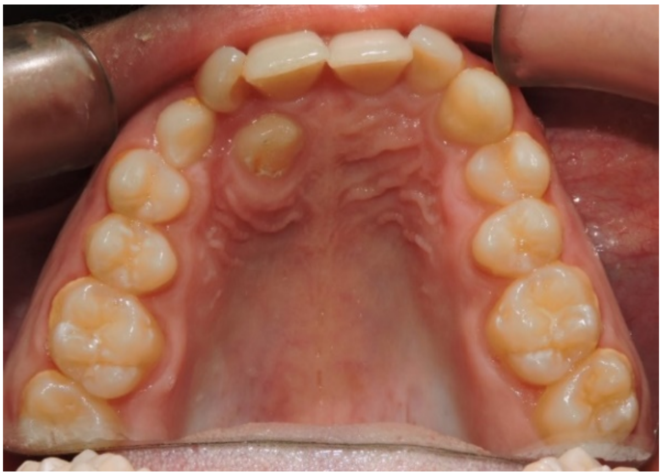


Figure 3: 16 weeks post laser exposure

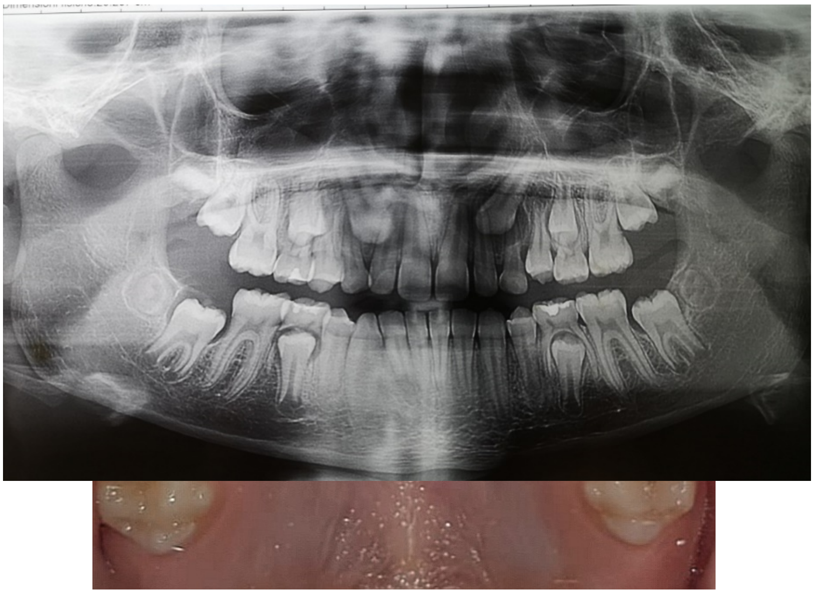
Case n.15

P.D., 13, female.

The young patient presented the impaction of the upper canines in the palate bone. The patient had a II Class dental malocclusion with deep bite.

She had not undergone previous orthodontic therapy. She had familiarity for upper canine impaction with the failure of the therapeutic plan that provided for the recovery of the canines, because of follicular cysts.

Rx OPT and the CBCT showed the deep bone inclusion of the canine, the proximity to the root of the lateral incisor, and the presence of cystic-like formations around the crown of the impacted canines.



Rx OPT

Figure 1: Before the laser surgery

Figures 2-3 : Details of Laser opercolectomy

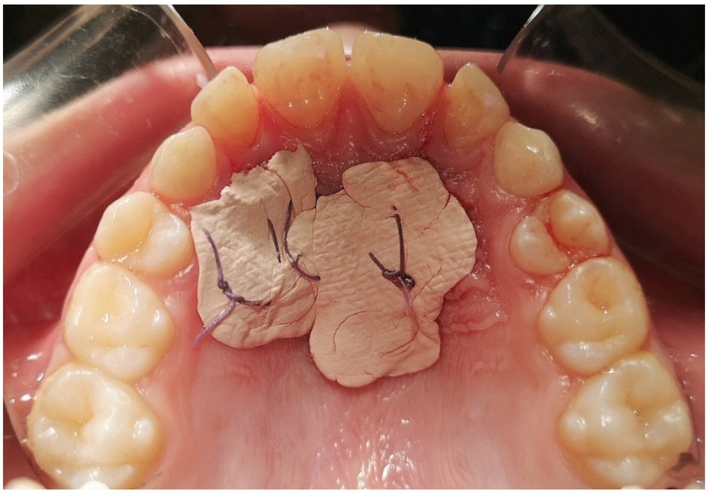


Figure 4: Application of the periodontal wrap

Figure 5: 1-week post-surgery

Figure 6: – 8 weeks post-surgery

Figure 7: 16 weeks post-surgery

Figure 8: 24 weeks post-surgery

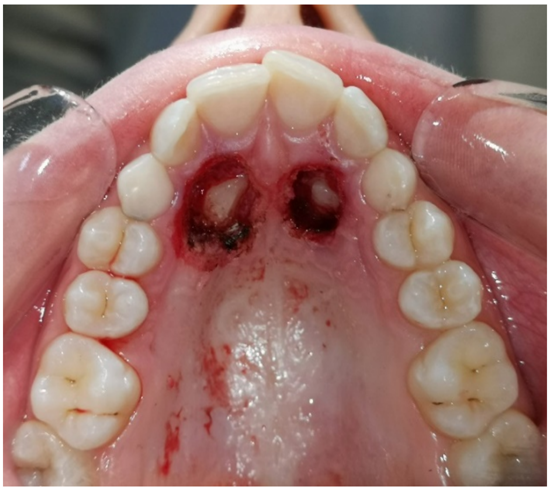
Case n.16

S.DC, female, 13 years.The intraoral examination showed the persistence of both the deciduous canines in the dental arch. There was also a very tapered upper dental arch with dental crowding, and lack of space for the alignment of the canines.

The patient had not undergone previous therapy and had a good oral hygiene and a good general health.

The CBCT showed deep impaction in the palatal bone of the upper canines. The prognosis of the canines was negative due to their excessive inclination (1.3: α=45°-2.3: α=31°).It was decided to attempt canine's recovery with laser surgery*.

Figure 1: Before the laser surgery



Figures 2-3: Laser operculectomy

Figure 4: 8 weeks post-surgery

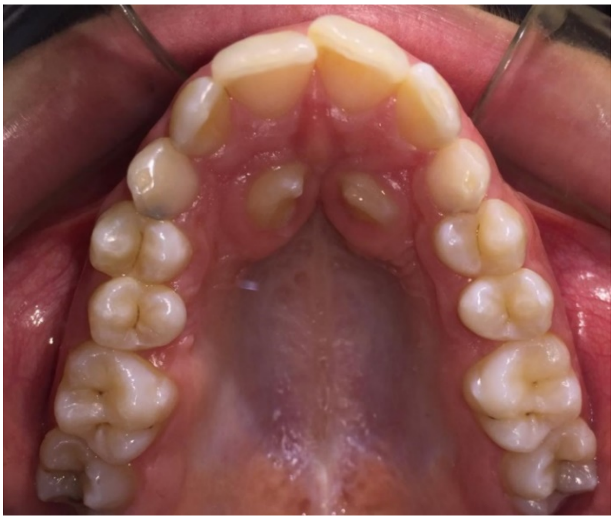


Figure 5: 16 weeks post-surgery

Case n.17

E.DA., female, 14. The patient had a palatal inclusion of the two maxillary canines. She had not undergone previous therapy and had good general health.

The intra-oral examination shows the presence of the deciduous in the arch, and a medium oral hygiene. The lateral incisors were both peg-shaped.

CBCT showed that the right canine was near to the lateral incisor, with an initial resorption of the root.

The prognosis of the canines was negative due to their excessive inclination (1.3: α=44°- 2.3: α=52°). The impacted canines were in a deep and mesial position.

Figure 1: Before the surgery

Figure2: 1-week after surgery

Figure 3: 8-weeks after surgery

Figure 4: 16-weeks after surgery

Case n.18

G.G., male, 15. The patient had the right upper canine impacted in the palatal mucosa.

The intraoral examination showed the persistence of the right deciduous canine in the dental arch, and the eruption of the left canine. Near the right lateral incisor, the “canine bulge” was palpable on the palate. This OPT and CBCT confirmed the diagnosis of impacted palatal canine. Moreover, the patient had small lateral incisor with an altered Bolton index and anterior diastemas were present in the upper dental arch.

The patient had not undergone previous therapy and had a good oral hygiene and a good general health.

Figure 1: Before the surgery

Figure 2-3: 1-week post-surgery (left), 8 weeks post-surgery (right)

CHAPTER 6: DISCUSSION

In recent years different have studied the results of low-level laser therapy (LLLT) during orthodontic tooth movement. Lasers with an output energy below 500 mW are proven to have a bio-stimulatory effect on the tissues without increasing the temperature of treated region above the normal body temperature. So, they have the potential to accelerate tooth movement by means of influencing the remodeling of alveolar bone without unwanted impacts on the tooth and periodontium. Histological investigations revealed that LLLT during orthodontic tooth movement can profoundly affect cell-mediated alveolar bone remodeling[145].

The literature also reports numerous applications of lasers in oral surgery (high-intensity laser), for example for opercolectomy to remove the soft tissue that overlies an impacted tooth[146].
However, the bio-stimulatory action of high-intensity lasers used to expose the crown of the impacted canines has not yet been demonstrated.

6.1 Literature Review on the Impact of LLLT on Orthodontic Tooth Motion

The studies currently presented in the literature show the influence of laser-assisted therapy on orthodontic movement on animals, highlighting that, when soft tissue and bone tissues were treated with LLLT, they demonstrated an accelerated process of tissue repair and neo-application with a consequent increase in the speed of OTM[147-148]. Moreover, it has been shown by several studies that OTM can result in quantitative and qualitative changes in periodontal tissues [149-150]. These changes in periodontal tissues induced by the orthodontic force are modulated by growth factors, bone metabolism, and some mediators such as interleukins-1ß and some enzymes which, during tooth movement, are increased in response to the orthodontic mechanical stress [151-153]. Isola et al. [154]demonstrated also that the test side (diode laser) showed a significant reduction in the average range of dental pain due to orthodontic traction at 3, 7, and 14 days after laser treatment.

Guram et al[155]: In this study, each quadrant in the maxillary and mandibular arches was divided into laser-treated and control groups. There was a 1.17–1.9-fold increase in the canine tooth movement rate during canine retraction in the laser-treated group. The outcomes were statistically noteworthy.

Dalaie et al[156]: The four quadrants were split into laser-treated and control groups at random. Patients initially underwent levelling and alignment using the sectional system; subsequently, Canines were retracted using sectional closing loops. The impact of laser irradiation on the measure of tooth movement was not considerable ($P = 0.45$). Additionally, the amount of movement in the maxilla was equivalent to that in the mandible ($P = 0.35$).

Kansal et al[157]: Left and right quadrants of the upper arch were randomly divided into the laser group and the control group to assess the efficacy of LLLT in the rate of canine movement during the canine retraction phase. The average value obtained for the control group from 1st to 63rdday was 3.30 ± 2.36 mm and it was 3.53 ± 2.30 mm for the laser group.

Qamruddin et al[158] : The maxillary arch was randomly split into the groups of experiments and placebo. After 9 weeks, canine retraction on the laser-treated side (1.60 ± 0.38 mm) was considerably higher than that on the placebo side (0.79 ± 0.35 mm; $P < 0.05$). On the laser-treated side, the general motion of the canines was 2.02 times higher than that on the placebo side.

Varella et al [159]: In this split-mouth study, at all of the time points, the quantities of canine retraction for the laser group were higher than those for the control canines ($P < 0.001$).

Üretürk et al [160]: Right maxillary canines were distalized as the control group while the left maxillary canines were distalized by laser application. In the laser group, the quantity of tooth motion was 40% higher than that in the control group after 3 months. The quantity of canine distalization in the laser group was significantly different in comparison with the control group ($P < 0.01$).

Sousa et al[161]: Mandibular or maxillary canines or both have been assessed during the retraction of the canines. Only one side of the arch was laser irradiated, whereas the other side was considered the control group. The movement of laser-irradiated canines was statistically greater than that of the control group in all evaluated periods ($P < 0.05$).

AlSayed Hasan et al[162]: Patients were allocated either to the laser group or to the control group at random. All patients received conventional fixed equipment orthodontic treatment. In addition, the patients in the laser group had an LLL regimen throughout the phases of levelling and alignment. The laser group needed less mean time (81.23 ± 15.29 days) to complete levelling and arrangement than the control group (109.23 ± 14.18 days; $P < 0.001$), which indicates a 26% decrement over the entire treatment time.

Genc et al[163]: The laser was applied when the retraction of the maxillary lateral incisors started. The right maxillary lateral incisors were considered as the laser group, whereas the left maxillary lateral incisors comprised the control group. In the laser-treated group, significant differences were observed over time in the distances between the lateral maxillary incisors and the maxillary central incisors compared to the control group ($P < 0.001$).

Youssef et al[164]: The canine retraction was accomplished in both upper and lower jaws. The right side of the upper and lower jaw was regarded as the laser group, while the control group was the left side. The speed of tooth motion was greater in the laser-treated side than that in the control side in the two jaws. There was no statistically significant difference between the upper and lower canine mean speed values ($P > 0.05$) and the jaw position did not influence the speed of tooth motion.

Heravi et al[165]: The canine retraction was once carried out solely in the upper jaw requiring first premolar extraction on both sides. One half of the higher arch was irradiated and another half was considered as the placebo group. They utilized two techniques to measure the extension of canine distal movement, and no significant difference was distinguished between the controlled and laser-treated sides by any of the measurement techniques.

Table X : shows all the results of the included studies.

Study ID	Outcomes
Guram et al[155]	LLLT can reduce the fixed orthodontic tooth movement duration.
Dalaie et al[156]	There was no significant difference in terms of tooth movement between the irradiated and non-irradiated sides at any time point (P >0.05).
Kansal et al[157]	There was no statistically significant difference in the rate of tooth movement during canine retraction between the laser group and the control group.
Qamruddin et al[158]	Low-level laser irradiation can accelerate orthodontic tooth. Movement and the Canine retraction was significantly greater on the experimental side compared with the placebo side.
Varella et al[159]	LLLT-facilitated orthodontics is approximately 2 times faster than conventional orthodontics.
Üretürk et al[160]	Low-level laser application significantly accelerates tooth movement in humans and could shorten the whole treatment duration.
Sousa et al[161]	A statistically significant increase in the movement speed of irradiated canines. This might reduce orthodontic treatment time.
AlSayed Hasan et al[162]	LLLT, used with the described parameters, is an effective method for accelerating orthodontic tooth movement in dental crowding cases.
Genc et al[163]	The application of a low-level laser could significantly accelerate orthodontic movement in humans.
Youssef et al[164]	LLLT can accelerate movement during orthodontic treatment.
Heravi et al[165]	LLLT did not accelerate orthodontic tooth movement

This experimental project was conducted in order to evaluate the effectiveness of laser surgery as an alternative approach to conventional surgical-orthodontic treatment.

After laser exposure, no orthodontics treatment was initiated until the impacted tooth had erupted sufficiently into the palate and the autonomous eruption capacity was assessed.

The spontaneous eruption was quantified by measuring the millimeter distance between the cusp of the canine one week after surgery (released from the overlying mucous and bone tissues) and the cusp of the same after 16 weeks from laser surgery.

Of the 26 canines under study all of them performed a movement between 2,72 mm and 7,04 mm (mean value: 5,01 mm).

Therefore, we can state that, at the end of the evaluation period of 16 weeks, a significant teeth movement was observed. Furthermore, the exposure of part of the dental crown, allowed, in all cases treated, to apply a bracket or a button to align the tooth in the dental arch.

Our data suggests that the response of the dental element to the bio-stimulant action of the laser, applied to expose their crown, can be considered effective.

Of the values obtained, the ones most distanced from the mean value were considered (the highest values 6,9 and 7,04 and the minimum values 2,72 and 3,12) and the type of inclusion of treated canines to which they refer was evaluated.
The four values correspond to canines in bone inclusion; in particular, the millimetric value 7,04 corresponds to a deep inclusion canine.

Therefore, from what emerges from our study, no significant correlation was found between the extent of spontaneous eruption (in mm) and the type of inclusion.
A further purpose of this study was the evaluation of the possible different action between the CO_2 laser (wavelength: 10600 nm; power: 4.5 Watts) used in super-pulsed emission mode (that no have bio-stimulation capacity) and the diode laser (wavelength: 980 nm + 645 nm; power: 4 Watts) used in continuous wave emission mode.

Comparing the millimeters of eruption of the canines treated with the two different types of lasers and applying the Student's T-Test, we found a super-imposable value.

This means that both lasers have the same bio-stimulatory action on the eruption of canines, regardless of their wavelength, power and emission mode. This leads us to think that it is the action of the laser itself that can stimulate the spontaneous eruption of the treated tooth.

Moreover, the study groups (group A and group B) and the control group were compared in terms of mean eruption time, respectively spontaneous or forced by means of a Crozat orthodontic device, activated monthly to allow the displacement of the canines .In the control group the duration of the orthodontic traction is, on average, 10 months. In the study groups the canine eruption was spontaneous and occurred in an average period of 4 months. It can be stated that, although a forced orthodontic traction was applied in the control group to allow tooth eruption, the eruption times in the study groups were significantly lower. The results obtained indicate the effectiveness of the new approach proposed by us, although performed on a small sample of patients. The results are significant from different points of view.

First of all, being young patients, is the increase in patient compliance because they are subjected to a minimally invasive surgery that does not require the application of orthodontic devices on the palate that can cause inconvenience and discomfort, beyond to compromised oral hygiene.
Moreover, in the conventional approach, mechanical eruption of impacted palatal canines may lead to prolonged treatment and the deleterious effects of prolonged orthodontic treatment are well-documented and include the propensity for greater root resorption and poor patient compliance. Additionally, root resorption of teeth neighboring the impacted tooth is thought to be accelerated if mechanical eruption is undertaken. The surgical approach with laser showed, compared to the traditional surgery, advantages already underlined in the literature: precision during the tissue incision, the need for a lower quantity of local anesthesia, the elimination of the use of sutures (with consequent reduction of infections and inflammatory processes). Furthermore, an antibacterial and disinfectant effect of the laser has been demonstrated, a property that improves post-operative admission and reduces the intake of antibiotics. Post-operative wound healing was rapid and patients reported less discomfort in the post-operative period and minor discomfort during speech and chewing. The young patients have resumed normal school and sports activities from the day after the surgery.
No patient complained of any pain or discomfort in the first post-operative check after a week.

CHAPTER 7. CONCLUSION

From this study, it emerged that monitoring with digital technologies is more precise than conventional monitoring, allowing us to make real measurements.

We could eliminate the error caused by manual measurement with ruler and compass on plaster casts.

Furthermore, digital monitoring allowed us to make assessments and comparisons over time of the same patient.

The analogical impression has errors which derived from the distortion of elastomeric impressions, disproportionate water/powder ratio of dental plaster and unsuitable storage conditions of physical impressions or gypsum casts.

With digital models fabricated from alginate impressions, fine details of tooth anatomy might be lost because of the limited ability of the impression material to flow into areas with undercuts, and potential shrinkage upon desiccation can compound the problem.

Digital models more accurately represent the intraoral situation because there are fewer sources of error. It is logical to assume that when processing steps are eliminated in the production of digital models, the models will be more accurate.

Regarding the sample under study, thanks to digital technologies we have been able to calculate the real eruption of the impacted canines thanks to the models obtained from the CT, which is not possible to evaluate analogically. We also calculated the areas with a software, which is not possible on plaster casts, nor from the photos.

We demonstrated in this way that laser surgery is effective.

The canines have spontaneously erupted on the palate over a period of 4 months on average 5,01 mm, in particular 2,95 mm from surgery to 2 months.

It is possible to define 4 months as the right time on average to perform the fixed orthodontic therapy and bring the canine to its physiological position in the arch, after its spontaneous eruption.

The T test suggests that the difference in eruption and in exposure of the palatal and vestibular areas in the two periods considered (0 – 2 months, 2 – 4 months) are statistically significant data, being the P-value lower than 0.05.

We also evaluated the approach of canines at the central and lateral incisor. It emerged that in one patient the canine approached the lateral incisor, in two cases it approached the central, in three cases it approached both.

We verified that it is due to the inclination of the tooth, evaluating the initial inclination of the canine from the CT; in this way, we excluded the possibility that this approach is due to the laser application.

Thanks to digital monitoring we evaluated the correlations between age, angle and type of inclusion and the eruption. It appeared that patients under 14 years old, responded to treatment with a larger eruption of 0,5 mm than patients over 14 years of age.

The canines with more than 30 ° responded similarly to those with an angle of less than 30° and in both groups the standard deviation is about 1 mm. So, the entity of the angle α in this case don't define the prognosis. The angle does not influence the response to treatment.

The canines with bone inclusion had a lower average eruption than those with mucosal inclusion. In particular, the eruption of canines with both type of inclusion is greater in the first two months, then slow down.

In conclusion, the patients under 14 years and the mucosal inclusion are two factors that have made the treatment more effective, considering the average eruption.

We performed the T test on patients' eruptions dividing them by age, angle and type of inclusion. The P-value is >0,05 but the average eruptions are not similar in two of the three cases. It emerged that the sample should be extended to demonstrate that the differences, between the two groups, are not due to chance and to refute the null hypothesis.

This is important because it may suggest that age-related factors (residual vis a tergo) and position (inclusion in bone or mucosa) of the impacted tooth may cause a better or worse response to treatment, with different movement of the tooth.

We also considered the speed of eruption of the impacted canines. We found that the average speed in 0-T1 (0,049 mm/day) is greater than that in T1-T2 (0,034 mm/day). The total speed in 0-T2 is 0,042 mm/day.

We could deduce from this data that the effect of the laser is more powerful in the first 2 months after the surgery and it tends to slow down afterwards.

The limitations of the study are the restricted sample of monitored patients, and the error due to the machine used for monitoring: CBCT, conversion programs, CS 3500 and other software. Another disadvantage is the cost of the intraoral scanner, but it is amortized over time.

This experimental project of doctoral research was carried out with the aim to demonstrate the efficacy of a new surgical-orthodontic approach which foresees the laser surgical exposure of impacted palatal canines not followed by the orthodontic traction phase with orthodontic devices.

We believe that our experimental approach is effective, in terms of shorter treatment time, fewer complications, minor discomfort and greater patient compliance, ideal characteristics of a treatment in the dental field.

Furthermore, our clinical studies comprehend a larger sample required to obtain statistically significant data.

In addition, future work will be focused on more detailed histological investigations, to evaluate, by means of tissue sampling and histological analysis, the cellular and tissue modifications generated by the laser action on an impacted canine

The study could be improved by increasing the patients monitored. The advantages found in this study are numerous. The main advantages of digital monitoring are the possibility of evaluating parameters that cannot be evaluated analogically and of making measurements of distances normally calculated on plaster casts with compass and rubber with the respective errors. Other advantages are represented by the reduction of work time, due to the abolishing of the need to request plaster casts to the dental technician. Which also means the reduction of the costs of the laboratory and it also means less costs for the patients.

By eliminating the steps of the analogue impressions and of the plaster casts, the details are certainly represented with more precision and accuracy and there is a minimum error accumulated. This digital workflow that is created is also managed entirely by a single person, which represents a further saving of time.

Moreover, we have clinical advantages, that are the less discomfort of the patient who does not tolerate the classic impressions in alginate and of the orthodontist, and the reduction of the chair time. The application of the digital technologies in the monitoring helps the orthodontist to make clinical decisions supported on measurable data and not just on clinical experience. The our ortho-surgical protocol with the use of different technologies set off to a new concept of work in dentistry, in particular, in the cases characterized by impacted teeth or cases that expect an orthodontic and surgical approach. Finally, a not indifferent aspect consists in the reduce of treatment time, which is an advantage for both the orthodontist and the patient. It is consequence of the reduction of the steps and work-time, and it is due to the real monitoring that can be performed on the patient.

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