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Volumetric changes after periodontal plastic surgery for the treatment of gingival recession: A new data collection method

Tesis doctoral
Presentada por **Tiago Miguel Santos Marques** para optar al título de Doctor en Odontologia

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ACRONYMS

Abbreviation	Definition
2DTHK	2D Mean Gingival Thickness Gain
2DTHKMax	2D Maximum Gingival Thickness Gain
3DTHK	3D Mean Thickness Of Tissue Over The Denuded Root
3DTHKMax	3D Maximum Thickness Of Tissue Over The Denuded Root
ASA	American Society Of Anesthesiologists
CAF	Coronally Advanced Flap
CAL	Clinical Attachment Level
CBCT	Cone-Beam Computed Tomography
CEJ	Cementoenamel Junction
CRC	Complete Root Coverage
CTG	Connective Tissue Graft
FGG	Free Gingival Graft
ICC	Inter Class Correlation Coefficient
IOS	Intra Oral Scanner
MRI	Magnetic Resonance Imaging
PRF	Platelet Rich Fibrin
RCT	Randomized Controlled Trial
RMS	Root Mean Square
ROI	Region Of Interest
RT1	Cairo Recession Type 1
RT2	Cairo Recession Type 2
RT3	Cairo Recession Type 3
SCTG	Subepithelial Connective Tissue Graft
STL	Standard Tessellation Language
TUN	Tunneling Technique
VISTA	Vestibular Incision Subperiosteal Tunnel Access

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RESUMEN

Introducción: El uso de software de análisis de modelos 3D podría ser útil para evaluar los cambios volumétricos de los tejidos duros y blandos tras intervenciones en la cavidad bucal.

Objetivos: Esta investigación pretende desarrollar y validar un nuevo protocolo digital para cuantificar objetivamente los cambios volumétricos de la cirugía plástica periodontal de cobertura radicular. Concretamente se se evaluaría el cambio volumétrico tras el tratamiento de la recesión gingival de Cairo tipos 1 y 2 (RT1 y RT2) cuando se realiza bien um injerto de tejido conectivo subepitelial mediante tunelización (TUN+CTG) frente a la incisión vestibular para tunelizar el injerto de tejido conectivo (VISTA +CTG).

Metodología: Se trataron 19 pacientes con recesión de El Cairo tipo 1 (RT1) o recesión de El Cairo tipo 2 (RT2) muestreados de forma consecutiva. Los modelos de estudio fueron digitalizados ópticamente al inicio del estúdio, a los 3 meses y a los 6 meses de seguimento para cuantificar las diferencias de volumen entre los distintos momentos de observación. El protocolo digital permitió cuantficar el volumen de tejido blando sobre la raíz desnuda, el porcentaje de tejido radicular.

Resultados: A los 3 meses de seguimiento, la cobertura radicular fue del 95,6% (± 14,5%) con técnica TUN+CTG y del 88,9% (± 20,5%) con la técnica de acceso al túnel subperióstico de incisión vestibular (VISTA+CTG), consiguiendose que la recesión disminuyera 1,33 (± 0,86) mm y 1,42 (± 0,92) mm, respectivamente ($p = 0,337$). A los 6 meses de seguimiento, la cobertura radicular fue del 96,5% (± 10,4%) con TUN + CTG y del 93,9% (± 10,3%) con VISTA + CTG. La recesión disminuyó 1,35 (± 0,85) mm y 1,45 (± 0,82) mm, respectivamente ($p = 0,455$). Se logró una cobertura radicular completa en 86,7% (± 0,4%) con TUN + CTG y de 70,6% (± 0,5%) con VISTA + CTG. No se encontraron diferencias estadísticamente significativas entre técnicas.

Conclusiones

El protocolo digital presentado demostró ser una técnica no invasiva para cuantificar resultados clínicos volumétricos tras cirugía plástica periodontal. Ambas técnicas reducen las recesiones gingivales, sin diferencias estadísticamente significativas. La covertura radicular completa osciló del 70.6 % al 86.7%., sin diferencias estadísticamente significativas entre las técnicas.

Palabras clave: recesión gingival, cobertura radicular, digital, análisis 3D, volumétrico, validación

ABSTRACT

Introduction: The development of intra-oral and laboratory scanners associated with 3D analysis software make it possible to evaluate volumetric changes in the hard and soft tissues of the oral cavity

Objectives: This research aimed to develop a new digital evaluation protocol to objectively quantify the volumetric changes of root coverage periodontal plastic surgery when combined with connective tissue graft and compare the tunnel technique with a subepithelial connective tissue graft (TUN+CTG) versus the vestibular incision subperiosteal tunnel access technique with a connective tissue graft (VISTA+CTG) in treating Cairo gingival recession types 1 and 2 (RT1 and RT2).

Methodology: Consecutive patients with Cairo recession type 1 (RT1) or Cairo recession type 2 (RT2) were treated. Accurate study models obtained at baseline and follow-ups were optically scanned. Healing dynamics were measured by calculating volume differences between time points. The volume of soft tissue over the denuded root was calculated using a new measuring methodology.

Results: Nineteen patients were treated between December 2014 and January 2019. At 3-month follow-up, root coverage was 95.6% (±14.5%) with tunnel and connective tissue graft (TUN+CTG) technique, and 88.9% (±20.5%) with the vestibular incision subperiosteal tunnel access and connective tissue graft (VISTA+CTG) technique. Recession decreased 1.33 (±0.86) mm and 1.42 (±0.92) mm, respectively ($p = 0.337$). At 6-month follow-up, root coverage was 96.5% (±10.4%) with the TUN+CTG and 93.9% (±10.3%) with the VISTA+CTG. Recession decreased 1.35 (±0.85) mm and 1.45 (±0.82) mm, respectively ($p = 0.455$). Complete root coverage was achieved in 86.7% (±0.4%) with TUN+CTG and 70.6% (±0.5%) with VISTA+CTG.

Conclusions

No statistically significant differences were found between techniques.

The digital protocol presented proved to be a non-invasive technique for accurate measurements of clinical outcomes. Both techniques reduce gingival recessions, with no statistically significant differences.

Keywords: gingival recession, root coverage, digital, 3D analysis, volumetric

I. INTRODUCTION

I.1 Gingival recession

Gingival recession is a condition that affects mostly adults when the root surfaces of one or more teeth are exposed due to an apical displacement of gingival tissues(1–4). It can have several etiologies, which may be grouped into anatomical factors (e.g., lack of attached gingiva(5), muscular insertions near gingival margins(6), tooth misalignment(7), inadequate thickness of the alveolar bone plate(8), and root prominences(9)), pathological conditions (e.g., periodontitis or viral infections)(10), and iatrogenic factors (e.g., improper restorations within the biological space and mechanical trauma(9), including trauma associated with tooth brushing or lip piercing)(11). This condition may be treated using a variety of therapeutic options with different degrees of success depending on the initial presentation and treatment approach. (12,13)

Studies testing different techniques, such as Coronally Advanced Flap (CAF) alone, Subepithelial Connective Tissue Graft (CTG) alone or in combination with rotated or advanced flaps, and guided tissue regeneration, have demonstrated that surgical treatment of exposed root surfaces improves clinical attachment levels (CAL) and reduces gingival recession in most patients, whereas on the other hand uncertainty exists about the real effect of the graft. (3,13)

Cortellini et al. compared in a RCT coronally advanced flaps for gingival recession treatment with and without the additional application of SCTGs.(14) The presence of a SCTG under the flap was associated with a reduced soft tissue contraction during the early phase of healing leading to a significantly greater amount of sites completely covered at 6 months. The graft might stabilize the flap in a coronal position and therefore serve as an “anchor” for the covering flap during the initial wound healing period.(15)

There is still some lack of knowledge about the tissue thickness over the denuded root. Very few studies (16) have attempted to quantify soft-tissue thickness over the exposed root. Specifically, flap thickness has been shown to predict root coverage in mucogingival surgery(17,18), with 1.1 mm being the minimum thickness to achieve complete root coverage. However, there is still a lack of information about the assessment of periodontal biotype changes and volume gain after a connective tissue graft.

All the presented studies use conventional methods such as periodontal probes with prefabricated stents to reduce variability . These methods do not allow to do a volumetric evaluation of the soft-tissue healing after periodontal plastic surgery. Recent developed methods, such as digital measurement of recession in cast models or directly in intra oral scan , as presented in the papers of Otto Zuhr and Alfonso Gil (19–22) have the capability to do a 3D analysis of the soft tissues and, as so, measurements in every anatomical plane with an accuracy not achieved by conventional methods.

Even if complete root coverage is obtained, other factors, such as the thickness and color or blending of the surgically treated area, must be taken into consideration to fulfill all the esthetic expectations of the patient. (23)

I.2 Soft Tissue Graft types

The application of soft tissue autografts has characterized the last 50 years of clinical periodontology, a variety of soft tissue grafting interventions is carried out with two different targets: increasing the width of keratinized tissue and increasing soft tissue volume.(15)

Although it is possible to use soft tissue from edentulous crests and gingival areas for grafts, the palatal mucosa is preferred due to its availability and ease of acquisition. Free gingival grafts (FGG) were the first method used to cover gingival recessions, increasing gingival mucosa thickness and keratinized tissue height.(24) They are taken from a superficial layer of the palate and consist mainly of lamina propria, containing a greater amount of fibrous connective tissue and a lower percentage of adipose tissue.(25) On the other hand, the subepithelial Connective Tissue Graft, taken from a deeper layer of the palate, consists mainly of submucosal tissue.(25)

Several authors argue that soft tissues may vary in thickness between individuals and within the oral cavity, depending on several factors: race, age, genetic factors (26–28), body weight (29), periodontal phenotype, arch size (30), and gender.(31) Bleeding and paresthesia are frequent complications after CTG harvesting.(32) So, it is important to select a zone where an adequate amount of tissue can be obtained without causing important health risks.(15)

Several CTG surgical techniques have been described. In 2009, Mcleod et al. (33) performed a de-epithelialized CTG – an FGG without the epithelial layer, removed from the palate itself before graft excision, and explained that it provided greater control of the de-epithelialization process. In contrast, Zucchelli G. et al. (2010) (34) reported a preference for de-epithelialization outside the oral cavity, where they checked if the epithelial tissue was completely removed under different incidences of light.

The development of soft tissue autografts from the FGG to the SCTG represents a paradigm shift, which is conceptually anchored in the literature by the transition from classical mucogingival surgery to plastic periodontal surgery.(15)

Although there seems to be a general consensus in the scientific community that additional thickening of the marginal gingiva with the use of autologous connective tissue grafts (CTG) can further enhance treatment outcomes and particularly improve the long-term prognosis of the results the written evidence is still inconsistent in this context, but they can be used for soft tissue thickening to stabilize the gingiva, for example, before orthodontic or restorative treatment and to mask discolored roots or shining through implant components.(15)

Grafts from the different sites differ in their geometric shape: grafts from the tuberosity are more voluminous, those from the posterior lateral palate rather thin, whereas those from the anterior palate can often be extensive with a large surface. This has an influence on the indication they are intended for.(15) Grafts from different donor sites vary in their histologic composition. It may be speculated that these differences not only account for variable volume stability but also influence the physiologic process of graft re-vascularization.(35) Grafts obtained from the posterior palate are denser and firmer so we can assume that they are less susceptible to postoperative shrinkage but being very dense appear to undergo necrosis more easily. (15)

After periodontal plastic surgery, besides evaluating the recession clinical result, the clinician should also control the soft-tissue stability at the donor area. Del Pizzo et al. (36) evaluated the initial healing of the palate based on color, comparing three different techniques: FGG, “single incision,” and “trapdoor.” They concluded that the “single incision” technique allowed for a faster and more complete epithelialization within 2 weeks, while the other two techniques required 4 weeks for this process. Those authors hypothesized that the healing delay in the FGG and “trapdoor” techniques might be due to removing the epithelial layer of the palate mucosa (36) and vertical releasing incisions.

Comparing patient morbidity after FGG and SCTG harvesting procedures demonstrated that post-operative pain was rather influenced by the thickness of the graft and the remaining soft tissue at the palate, the deepithelialized autografts consisting of lamina propria led to a statistically significant higher increase in buccal gingival thickness following recession coverage.(34)

Moreover, Keskiner et al.(37) carried out a study on the FGG technique and suggested that the filling of the intervention site would be faster with at least 2 mm of residual tissue, while if there were less than 2 mm, the filling could take more than 6 months, mainly at the center point. This finding indicates that second-intention healing does not occur uniformly over the entire length, being more advanced at the edges.(38)

I.3 Surgical Techniques

Periodontal plastic surgery is a procedure aimed at preventing and correcting defects in the gingival and alveolar mucosa or the bone tissue caused by anatomical, traumatic or disease-induced changes (39) A significant portion of these surgeries is intended to cover recessions caused by the soft-tissue apical migration that exposes the root surface or implant.(40) They are also often conducted to increase the keratinized tissue. The rationale behind using connective-tissue graft (CTG) is related to several aspects: quantity of existing keratinized tissue,(41) thickness of the gingival mucosa, dimensions of the recession, and the operator's skills.(42)

Multiple studies have documented simultaneous treatment of contiguous recession defects using large, partial-thickness, coronally advanced envelope flaps, often including connective tissue grafts(12,43). The tunnel approach with connective tissue grafts keeps papillary integrity and avoids vertical releasing incisions, allowing the treatment of multiple contiguous recession defects(23). Similarly, buccal recession coverage with free autogenous soft-tissue grafts of epithelium and connective tissue has also provided consistent clinical results(23,44,45). These grafts' success has been attributed to the double-blood supply at the recipient site from the underlying connective tissue base and the overlying recipient flap(46,47).

However, the use of the intrasulcular approach to creating either a sub- or supraperiosteal space to extend beyond the mucogingival junction followed by the placement of a connective tissue graft is technically demanding(12) and has several disadvantages, such as the risk of perforation or trauma of the sulcular tissues(12), accidental papilla laceration, reduced coronal mobilization of the flap, reduced access for graft placement, and reduced papilla mobilization. The current techniques limitations also include scar formation at the recipient site resulting from surface incisions, yielding possible unfavorable healing outcomes(12,48). On the other hand, it is assumed that avoiding visible incisions on the tissue surface allows for improved esthetics due to minimal soft-tissue trauma and post-operative scar tissue formation without complications during the healing phase(49,50). Therefore, the vestibular incision subperiosteal tunnel access (VISTA) technique was developed to overcome some of the main drawbacks of other tunnel techniques reported in the literature(12).

Over the time, after periodontal surgery, a known phenomenon named creeping attachment occurs, which increases the attached gingiva width around the tooth and stops the progressive gingival recession.(51)

I.4 Digital evaluation of surgical results

Several methods have been described for evaluating volumetric changes that range from calipers, dental casts, mucosa piercing with needles, probes or endodontic instruments, cone-beam computed tomography (CBCT). Transgingival piercing approaches have been frequently utilized for evaluating gain in gingival thickness following root coverage procedures in natural dentition.(52)

The palatal mucosa has been evaluated using different techniques, some more clinically invasive than others, to provide surgeons with more information. Measurements using endodontic files (18), anesthesia needles (53), histological sectional measurements (25), and, particularly, periodontal probes (26–29,54) are considered more invasive. On the other hand, computed tomography (CT) (55), cone-beam computed tomography (CBCT) (56), and ultrasonic devices (30) are considered non-invasive; however, CBCT has the drawback of ionizing radiation.(52)

The use of a needle may pierce the periosteum or the palatal bone, inducing errors with higher values (19), so using the periodontal probe is preferred.(13) Another probing method uses an endodontic file with a silicone stop, but its displacement can influence the measurements.(57) Moreover, all these methods require a reproducibility guide and anesthesia and are subject to operator error, being more appropriate for surgical procedures than pre- and post-surgical evaluations.(58) Bypassing the pain issue, the ultrasound was suggested as a non-traumatic alternative and proved to be faster and more accurate than the other methods; however, it is a sensitive device requiring multiple measurements to overcome possible errors.(30)

Magnetic resonance imaging (MRI) allows the assessment of soft and hard tissues without using ionizing radiations. Although some possible advantages of MRI in the oral cavity have been described, its use in dentistry is still very limited and further studies are needed to assess its applicability, accuracy and cost-benefits.(52)

None of the previously described methods were established as a standard for the dimensional analysis of soft tissues. Hence, intraoral scanning may be considered a promising method, as it allows using digital software to measure absolute thickness at various points and volume, defining the areas to be analyzed. This digital method offers some great advantages, including its non-invasive nature, high reproducibility, and excellent measurement accuracy.(59) It provides an unforeseen precision in evaluating surgical graft harvesting regarding both two-dimensional measurements and 3D evaluations (soft-tissue thickness/volume). Anyhow, these measurements require training and time. The development of intra-oral and laboratory scanners associated with 3D analysis software make it possible to evaluate volumetric changes in the hard and soft tissues of the oral cavity.(52)

Optical scanners have been introduced in dentistry for obtaining digital impressions and generating three dimensional digital images formatted as Standard Tessellation Language (STL) files.(60) STL files can be generated using intraoral chair-side scanners (direct technique) or by scanning dental casts with desktop/laboratory scanners (indirect technique) The direct technique allows to reduce the number of steps necessary to obtain digital files minimizing patient discomfort while, on the other hand, the use of laboratory scanner may result in a higher precision of the digital impressions, but it requires additional steps that may introduce some inaccuracy.(52) Intraoral scanners have had a significant improvement in the last years to a point where direct digitalization may soon replace the use of indirect techniques.(61)

Digital imaging techniques for outcome measures allows the longitudinal quantitative evaluation of volumetric changes by superimposing 3D images generated at different time points.(52)

Baseline data set is used as reference for the matching of the subsequent 3D images. Adequate structures for referencing are needed to be able to precisely match the 3D. These reference structures need to remain stable during the observation period. Normally, surfaces of teeth and fixed reconstructions are used as reference structures.

The rapid development in the field of computer-aided dental image analysis results in a large variability in the digital evaluation methods. In the last decade, several novel acquisition and digital evaluation approaches were presented in this field. (20–24) This technology was first described to measure in vitro alveolar ridge defects. It has been adopted in some experimental clinical studies to measure soft tissue and volumetric changes allowing the assessment of outcome interventions. Nonetheless no guidelines are implemented to standardize the assessment methods and a high degree of variation exists in the executed workflow which renders the comparison of study results unfeasible.(52)

In combination with computer software, these imaging methods allow precise and reproducible assessment of implant-related parameters such as the volume of peri-implant tissues, the implant position, the color of the mucosa and of the reconstruction, and the prosthetic fit.(52)

I.5 Digital evaluation of gingival recession

Concerning periodontology, there are publications in the dental literature that use optical scanning-based digital technologies, for evaluating volumetric changes following implant placement, soft tissue augmentation at implant sites, ridge augmentation, ridge preservation and root coverage procedures.(62–66) The workflow for generating and analyzing STL files, as well as the outcome measures for reporting the volumetric changes have not been systematically assessed in the literature. This method proved to improve measurement reproducibility (Digital Volumetric Assessment of Gingival Changes), lowered intra- and inter-individual variance of measurement , and set the threshold for CRC to 0.01 mm of remaining gingival recession.(59,65,67) Therefore, no rounding errors must be accepted, and CRC is only recorded, when the gingival margin actually reaches or exceeds the CEJ. There is only little data on soft tissue stability after surgical root coverage procedures with and follow-up of 5 years or longer.(22) The results of a 5-year follow-up examination on coverage of mucosal recessions at dental implants using epithelialized grafts after extraoral deepithelialization point to an influence of the harvesting technique in the thickness gained, superficial layers of the lamina propria seem to show more stability but can have aesthetic disadvantages. (68) Digital evaluation seems to be a promising approach for clinical and research evaluation of gingival recession dimensions, and of the stability of the aesthetic outcome in the anterior regions in combination with the existing analogical criteria.

Therefore, this research aimed to develop and present a new digital evaluation protocol to objectively quantify the volumetric changes of root coverage periodontal plastic surgery, particularly the tunnel and VISTA techniques combined with connective tissue graft, with a 3- and 6-month follow-up, to better satisfy the precision demanded by the improvement of the microsurgical techniques.

II HYPOTHESIS AND OBJECTIVES

II.1 Hypothesis

The null hypothesis established was there is no significant differences on root coverage outcomes when applying two different periodontal plastic surgical techniques in comparison with baseline volumes.

It was hypothesized that periodontal plastic surgery will increase the volume of soft tissues and reduce the amount of exposed root after 3 and 6 months.

Intraoral 3D scanners along with a specific software allow to make an accurate assessment of surgical root coverage outcomes with regard to both two-dimensional (recession depth) as well as three-dimensional (soft tissue thickness/volumetric) evaluations. This standardized protocol is named: Digital Volumetric Assessment of Gingival Changes

IIII.2 Objectives

- To present an innovative methodology that can be applied as a measuring method for evaluating the outcomes after surgical root coverage with a high precision not described yet in current literature.
- To examine three-dimensional soft tissue aspects following root coverage with either the tunnel technique with subepithelial connective tissue graft (TUN) or vertical incision with connective tissue graft (VISTA).
- To incorporate the findings of this volumetric studies in a global context regarding gingival recession treatment.

The secondary objective is to compare the clinical performance of the tunnel technique with subepithelial connective tissue graft versus a Vestibular incision subperiosteal tunnel access technique with connective tissue graft for the treatment of gingival recession defects (RT1 and RT2).

The main aim is to quantify volumetric changes of gingival recession after periodontal plastic surgery to better satisfy the precision demanded by the improvement of the microsurgical techniques.

II MATERIALS AND METHODS

The study protocol was approved by the Ethics Commission for Health of the University (Comissão de Ética para Saúde da UCP, Report number 25, 4th of June 2020). Informed consent was obtained from all participants and all methods were performed in accordance with the Declaration of Helsinki principles for medical research involving human subjects and following the requirements established by Portuguese Law n.º 21/2014 for clinical research. All surgeries were performed by the same surgeon (T.M.), aiming to achieve the best possible clinical outcomes for the patients and without a priori consideration of this retrospective research protocol, which was developed after completion of the patient surgeries (June 2020). Therefore, the surgeon was unbiased in his pursuit of the surgical procedures.

III.1 Participants

All participants were selected consecutively among the patients that visited the Periodontology Area of the University's Dental Clinic. Patients with no loss of interproximal attachment (Cairo recession type 1 (RT1))(69,70) or loss of interproximal attachment equal or not greater than the buccal attachment (Cairo RT2) treated in the University's Clinic were enrolled in the study. Those patients exhibiting single or multiple adjacent gingival recessions were treated, and all defects were included in the data collection. No single case was missed, overseen, or excluded. Teeth presenting root steps at the CEJ level and/or presence of root/crown abrasion and teeth presenting any sort of malpositioning were not excluded from the study.

The clinical criteria of the surgeon to choose one technique over the other was related to the gingiva biotype and the root coverage procedure to be performed, according to the literature on this issue:

thin biotypes were allocated to the VISTA technique and thick biotypes to the TUN technique(12). Interestingly, all Cairo RT2 recessions were included in the VISTA+CTG group.

Patients with one or more gingival recession defects who satisfied the following inclusion criteria were included:

a) Periodontally and systemically healthy patients (for example, patients with ASA classifications I and II);
b) Minimum of one Cairo RT1 or RT2 buccal or lingual gingival recession defect;
c) Full-mouth plaque and bleeding scores ≤20%, no pocket depths >3 mm, no active periodontal disease;
d) Clinical indication and/or patient request for recession coverage;
e) Radiographic evidence of sufficient interdental bone

Exclusion criteria were the following:

I.1 Cairo RT3 recession defects;
II.1 Smokers;
III.1 Teeth with cervical restorations
IV.1 Patients unable to undergo minor oral surgical procedures;
V.1 Patients with a history of drug or alcohol abuse or psychiatric disorder;
VI.1 Pregnant patients;
VII.1 Uncontrolled periodontal disease or patient’s unwillingness to undergo needed periodontal therapy around remaining teeth;
VIII.1 Patients who had any systemic condition that could contraindicate any other surgical procedures.

III.2 Study

This research was designed as a retrospective cohort study. A post-hoc statistical analysis indicates that this study would require a sample size of 102 for each group (i.e. a total sample size of 204, assuming equal group sizes), to achieve a power of 80% and a level of significance of 5% (two sided) for pre-post intrasubject comparisons based on recession changes. However, the periodontal plastic surgeries performed in the University Dental Clinic in the time-frame of this research were fewer, allowing to record data only from 19 patients with 38 recessions (31 RT1 and seven RT2). With this reduced sample size, the post-hoc power was only 8%. Hence, this was considered a pilot research where a new digital evaluation protocol was used to objectively quantify the volumetric changes of root coverage periodontal plastic surgery techniques.

The clinical outcomes were digitally evaluated by a different researcher (N.M.S.), blinded to the treatment technique. This researcher did not know the case and the technique used. A number was assigned to each case, not having any kind of identification.

Using an intraoral scanner (Intraoral Scanner DentalWings; Straumann, Basel, Switzerland), at baseline, 3 months, and 6 months, the scans were performed by the same operator (N.M.S.), following the manufacturers scanning protocol limited to the quadrant or sextant affected by the gingival recessions.

III.3 Pre-surgical preparations

Periodontal basic therapy was performed in all participants before surgery, included oral hygiene instructions and motivation, dental prophylaxis, and low-abrasive air polishing (Perio-Mate; NSK, Eschborn, Germany) as means of plaque removal.(71) Patients were required to use an atraumatic brushing technique with a soft toothbrush (Elgydium Clinic 7/100; Pierre Fabre Oral Care, Paris, France) or electrical toothbrush (OralB Smart 1500 Electric Rechargeable Toothbrush; Procter & Gamble, Cincinnati, Ohio, EUA) to eradicate harmful habits associated with the gingival recessions.

III.4 Surgical protocol

Following local anesthesia, root planning of the exposed root surface was performed with Gracey curettes (LM; LM-Instruments Oy, Parainen, Finland). Then, the residues were removed by copious irrigation with a sterile saline solution. The tunnel approach (Figure 1) was performed basically according to Zuhr et al.'s (2007) descriptions of a modified microsurgical tunnel technique (72) and used in several randomized control trials (16,19,22) . Following an initial sulcular incision with a microsurgical blade (SB004/BW064; MJK, Marseille, France), tunneling knives and blades were used to create a partial thickness flap, to develop a continuous tunnel in the buccal soft tissues. The supra-periosteal dissection was extended well into the mucosal tissues for sufficient flap mobility. Papillae were carefully detached by a full-thickness preparation in their buccal aspect, thus allowing for a coronal displacement of the mobilized buccal soft-tissue complex(16).

Figure 1- Tunnel technique surgical diagram

The VISTA+CTG technique (Figure 2) was performed according to Zadeh et al.'s descriptions of a modified microsurgical tunnel technique(12). The VISTA approach was performed with a mucosal buccal access incision distal to the recession defects being treated. Mucosal and intrasulcular incisions around the involved tooth were performed using microsurgical blades and specially designed tunneling knives (Tunneling Kit; Deppeler, Role, Switzerland), creating a mucoperiosteal tunnel exposing the facial osseous plate and root dehiscence. This tunnel was extended at least one or two teeth beyond the ones requiring root coverage to mobilize gingival margins and facilitate coronal repositioning, employing the same tunneling knives. Additionally, the subperiosteal tunnel was extended interproximally under each papilla as far as the embrasure space allowed, without making any surface incisions through the papilla. Finally, to achieve complete mobilization of the flap, the interdental papillae were gently undermined using a specially designed tunneling knife (Tunneling instrument TKP; Deppeler, Role, Switzerland)(47).

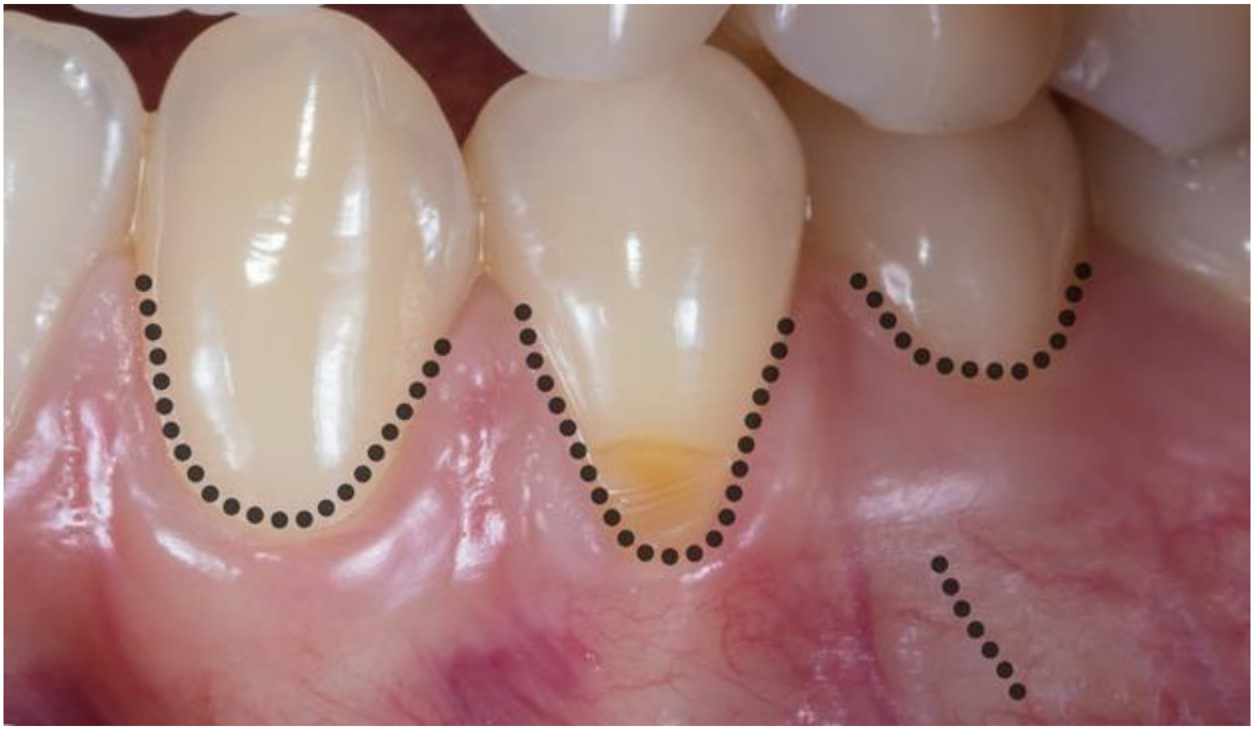

Figure 2 - VISTA technique surgical diagram

The surgeon chose a de-epithelization approach of the posterior palate for CTG harvesting. The graft was thinned to a thickness of 1–1.5 mm and then slid into the previously created tunnel using a monofilament suture (Dafilon 6/0; BBraun , Melsungen, Germany). Single Sutures were used to stabilize the graft mesially and distally. To achieve a coronal stabilization, compression a double-crossed suture was used, with composite anchor points on the contact points. (73)

On the donor site a tissue adhesive was applied to protect the wound, thin layers of a high viscosity blend of n-butyl and 2-octyl – cyanoacrylate tissue adhesive (Periacryl 90 H; GluStitch Inc., Vancouver, Canada) were applied and rinsed with saline until hemostasis was achieved.

III.5 Post-surgical protocol

The post-surgical protocol was adapted from Zuhr et al(72). The patients received 600 mg of ibuprofen (Spidifen 600; Zambon, Bresso, Italy) after the surgical procedure to reduce swelling and were instructed to avoid any mechanical trauma in the surgical site for 2 weeks. In addition, patients were instructed to rinse with Chlorhexidine digluconate 0.12% (Eluperio; Pierre Fabre Oral Care, Paris, France), three times per day for 2 weeks.

Two weeks after surgery, patients started to clean the teeth in the post-surgical area with a soft brush or electrical toothbrush. Every patient was recalled 3 months and 6 months post-surgery when clinical data were recorded, impressions were made, and casts were fabricated.

III.6 Digital measurements at baseline, 3 months, and 6 months

Accurate models were obtained at baseline and succeeding follow-up examinations, always under the same protocol: alginate impressions (Orthoprint; Zhermack, Badia Polesine, Italy) and gypsum study models (Vel-Mix white die stone; KERR, Bioggio, Switzerland), according to the manufacturer's instructions. This methodology was based on the publications of Gil et al(21,74).

These models were optically scanned with Intraoral Scanner (DentalWings; Straumann, Basel, Switzerland). The process has an accuracy of 20 µm (single unit), 50 µm (full arch) according to Dental Wings testing standard(75).

A new methodology that uses computerized measurement tools and design software was applied with Geomagic Control X (Geomagic, Morrisville, EUA) and Magics 23 (Materialise; Materialise, Leuven, Belgium). This software was used to virtually superimpose on each clinical case's pre-operative 3D images the subsequent follow-up scans and match them into one common coordinate system. All digital measurements were recorded to the nearest 0.01 mm as in Zuhr et al(19). The tooth surfaces were used as reference points for superimposing the different optically acquired files, allowing for accurate assessment of soft-tissue profile over the 6 months. A final alignment was done through the best-fit alignment algorithm(18).

III.7 Protocol for digital analysis model alignment

The T0 and T1 STL files were aligned using several functions:

“Align Between Measured Data Autoguess” – “Local Based on Auto Guess” (Figure 3). Define the STL T0 as “Reference” and the STL T1 or T2 as “Moving”, respectively.

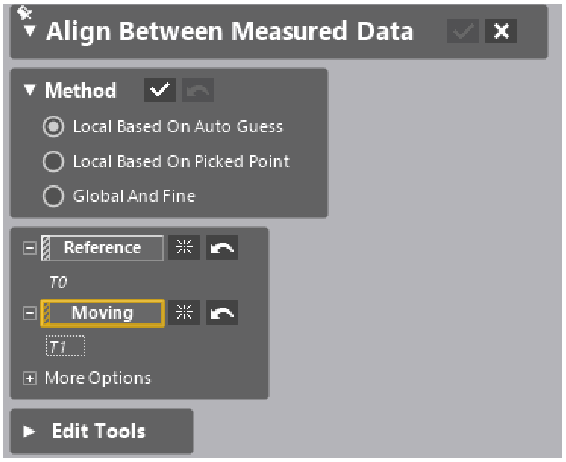

Figure 3 – Alignment Method

“Align Between Measured Data” – “Global and Fine”. (Figure 4)

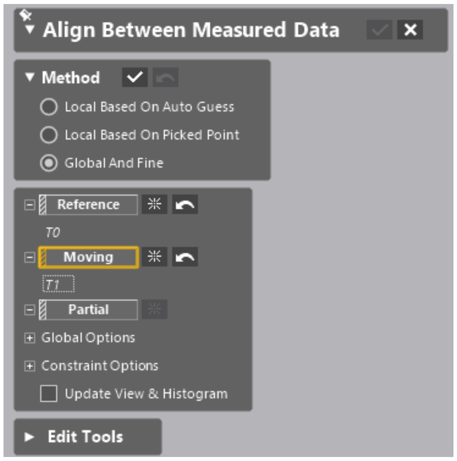

Figure 4 *– Alignment Method (Global and Fine)*

“Sampling Ratio”: 25%; “Max. Iteration Count”: 20; “Max Average Deviation”: 0.0001 mm; (Figure 5)

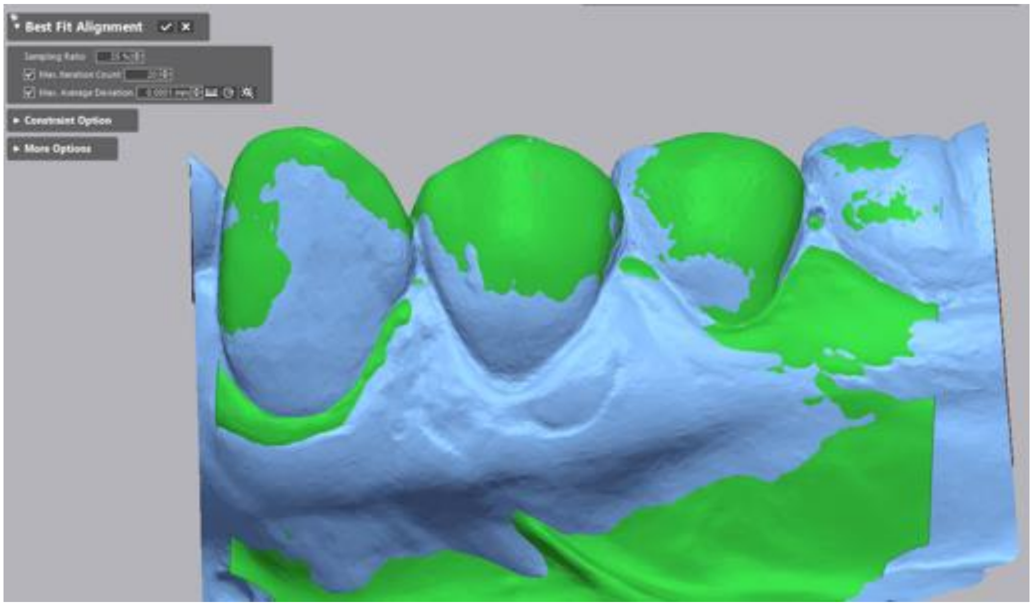

Figure 5- Best Fit Alignment settings (first alignment)

Best Fit Alignment”: “Sampling Ratio”: 50%, “Max. Iteration Count”: 20, “Max Average Deviation”: 0.0001 mm. (Figure 6).

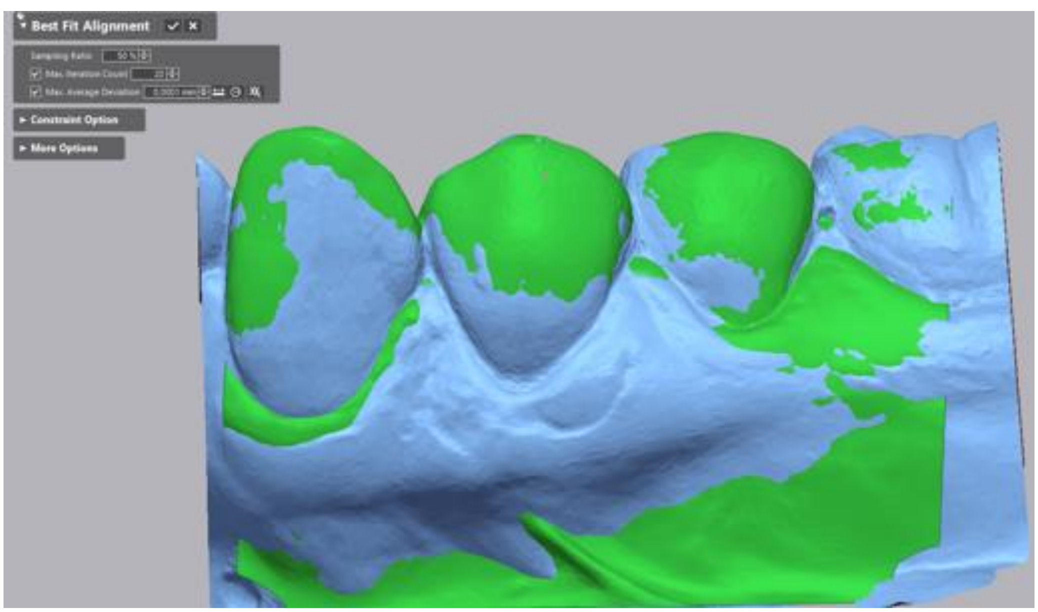

Figure 6- Best Fit Alignment settings (second alignment)

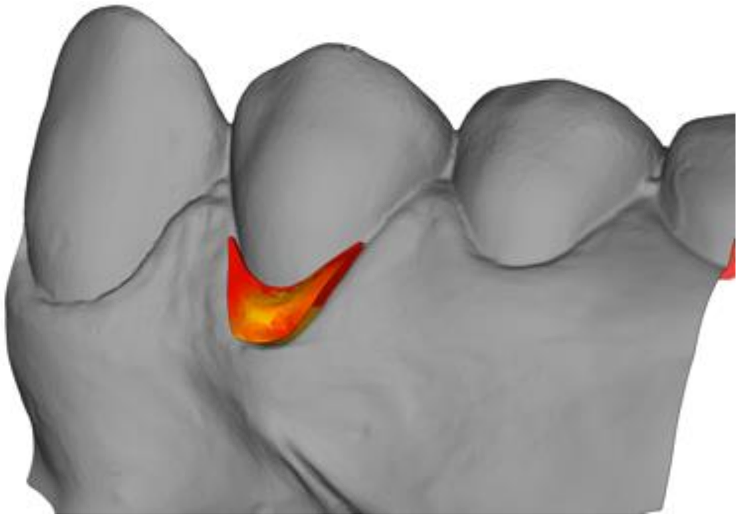

Figure 7- Volume over denuded root

Protocol for the digital analysis's 3D measurements
Geomagic® software
3D Compare function: creates a map of colors (from +2 mm to -2 mm, with a tolerance of ± 0.2 mm) to evaluate the volumetric changes that occurred in the surgical area.
Spline function: a coronal section was defined through the cementoenamel junction and mucogingival midline points, and several perpendicular planes with 0.1 mm between them were created. These perpendicular planes' mesial-distal distance corresponded to the mesial-distal tooth width. In the intersection of these two planes, standardized points were created in each case to evaluate the tissue thickness covering the previously denuded root.
This software allows saving the coordinates of the previously measured points so that the same measurements are applied in the following recalls in a precise and reproducible way.
Multiple 2D Compare function: creates a rectangular section standardized for each root coverage case, starting at the mucogingival line and ending at the cementoenamel junction. These limits were used to determine the region of interest for the measurements at the different time points, to perform an accurate and rigorous evaluation.
Magics 23 Materialise® software
STL files → mesh surface converted to a solid model → boolean operation T1 – T0 → solid model representing volume changes.
The recession was delineated at T0, T1, and T2 at the same time using transparencies, and the new volume of tissue over the denuded root was obtained, allowing precise quantification of the tissue.

Table 1 Protocol for digital analysis.

The following variables were analyzed fully digitally with the aforementioned software:

a) gingival margin thickness (baseline); (Figure 8)

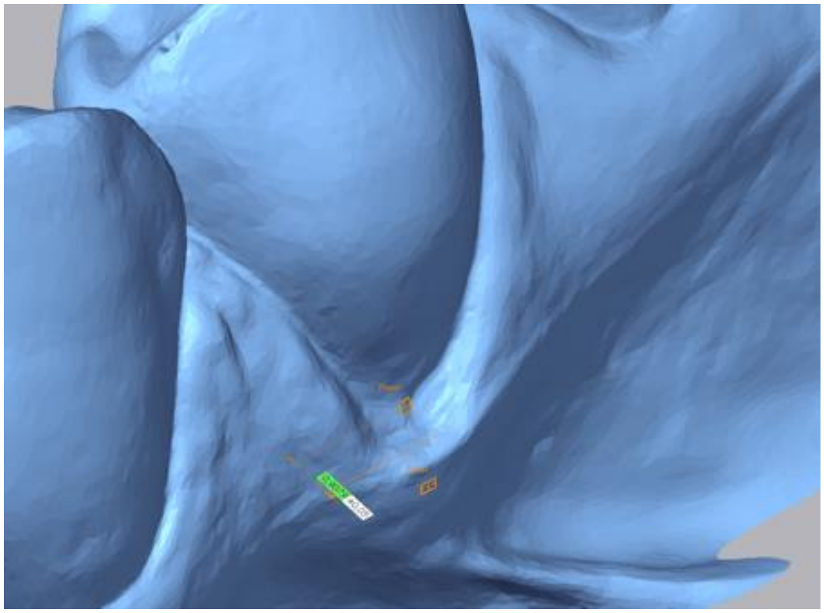

Figure 8 - Automatic measurement of gingival margin thickness

a) recession depth measured from CEJ to the gingival margin at the central buccal site; (Figure 9)

b) area of the gingival recession; (Figure 9)

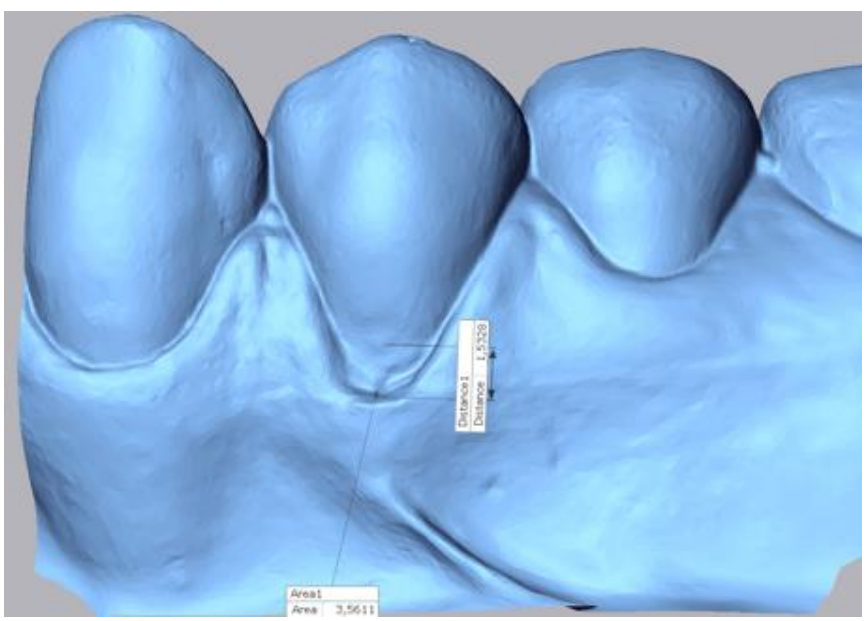

Figure 9 - Digital measurement of area and recession depth

c) height of the gingival margin papillae; (Figure 10)

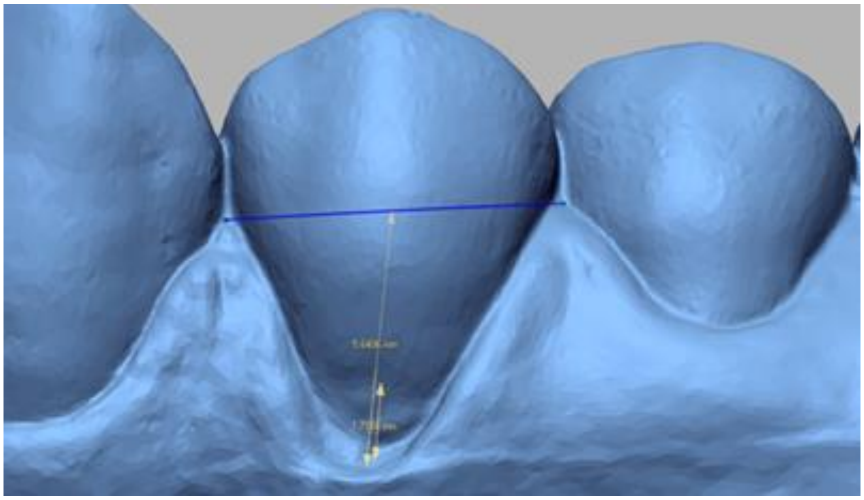

Figure 10 - Technique for measurement of pappila height

d) recession reduction;

e) area reduction;

f) complete root coverage;

g) 2D mean gingival thickness gain at 3 months and 6 months (2DTHK); (Figure 11)

h) 2D maximum gingival thickness gain at 3 months and 6 months (2DTHK Max);

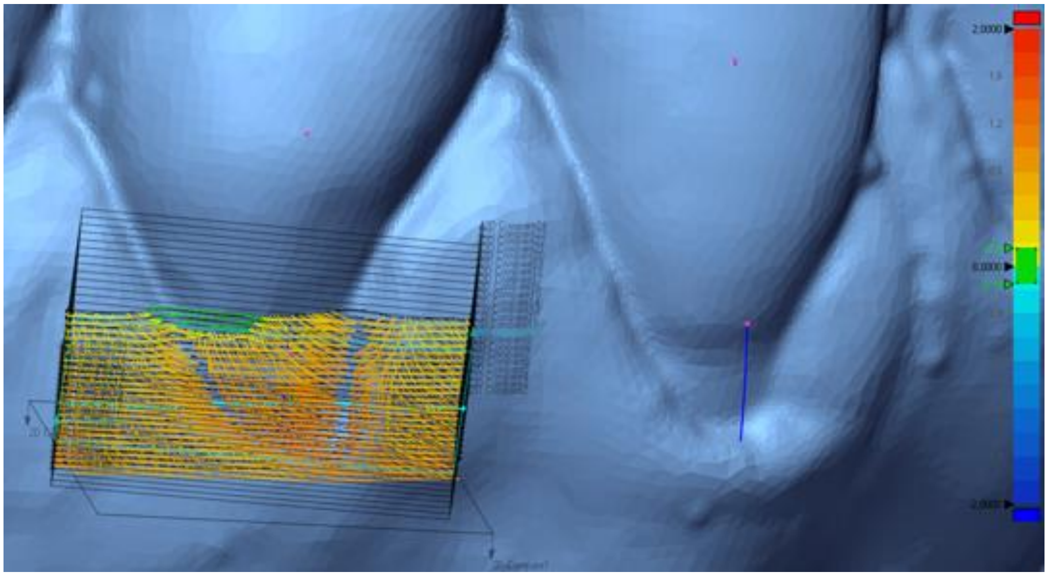

Figure 11 - ROI for 2D measurements

i) volume over the denuded root at 3 months and 6 months; (Figure 7 and Figure 12)

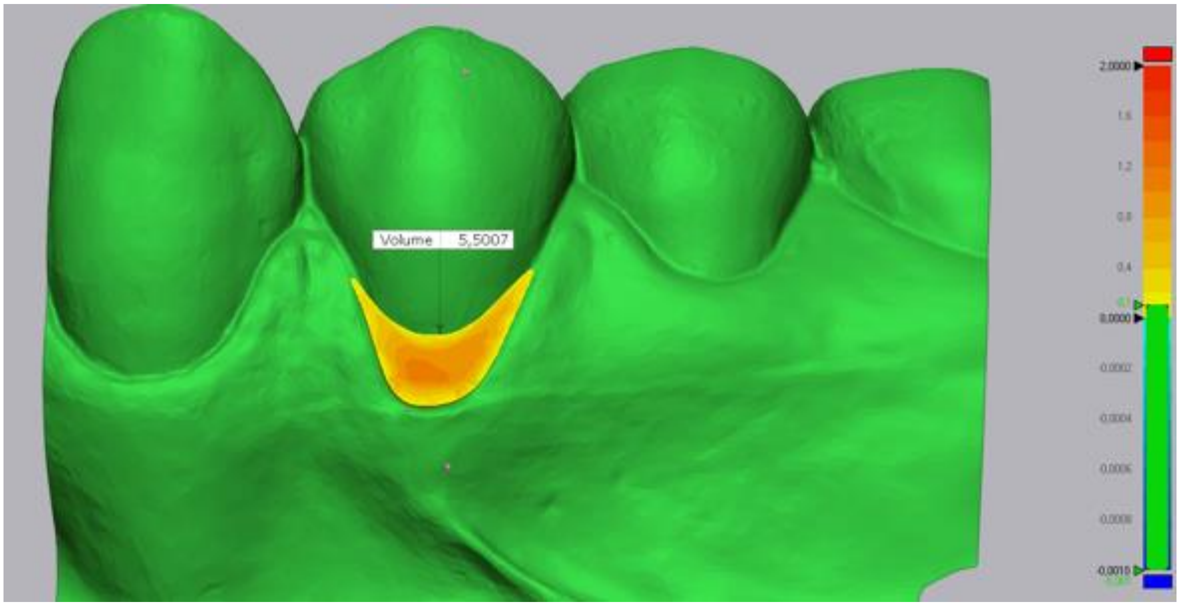

Figure 12- Soft tissue graft over denuded root volume

j) 3D mean thickness of tissue over the denuded root at 3 months and 6 months (3DTHK); (Figure 13)

k) 3D maximum thickness of tissue over the denuded root at 3 months and 6 months (Figure13) (3DTHK Max).

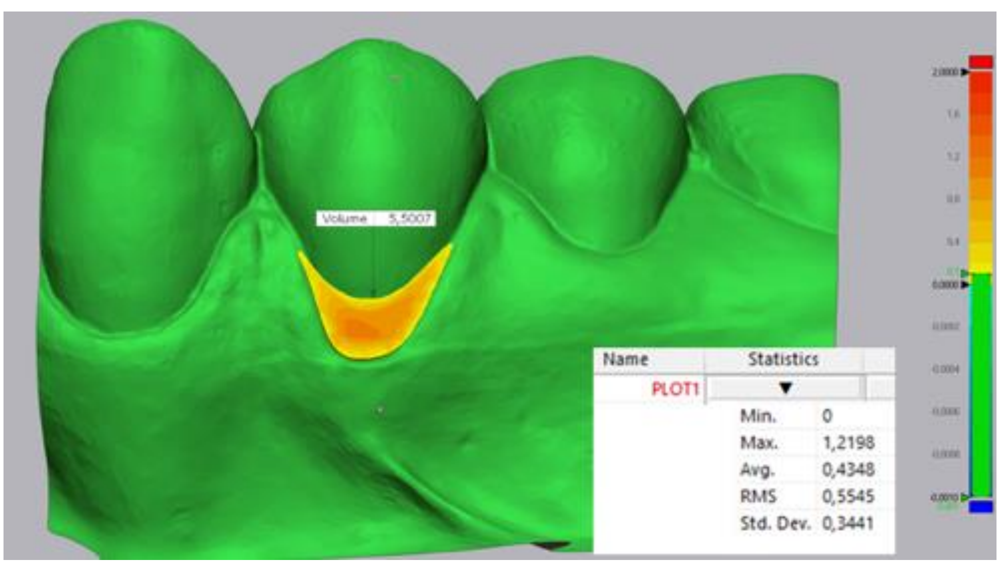

Figure 13 - ROI for 3D measurements

Two different methods to measure the soft-tissue thickness were applied using the protocol presented in Table 1.

The first method calculated the mean gingival thickness (2DTHK) and maximum gingival thickness (2DTHK Max) for each case at every time point, as seen in Figure 14.

The second method involved a 3D assessment by limiting the recession in T0, T1, and T2 at the same time using transparencies to obtain the new volume of tissue over the denuded root for precise quantification of the tissue, as seen in Figure 15. In this case, the region of interest comprised the entire area of grafted soft tissue on the previously exposed root surface. Thus, the mean thickness of the marginal soft tissue (3DTHK) on the formerly exposed root surface, the mean gingival thickness (3DTHK), and maximum gingival thickness (3DTHKMax) were assessed for each case and each time point. Gingival margin thickness was measured using a new method that allows quantifying the margin thickness in a non-invasive way, as shown in Figure 16: two planes are defined, and the software calculates the distance between those two planes. To measure the volume of tissue over the tooth the recession was delineated at T0, T1, and T2 at the same time using transparencies, and the new volume of tissue over the denuded root was obtained, allowing precise quantification of the tissue. A relative volume had to be considered at T1 as 100% so that we could compare with the volume changes that happened in the following 3 months.

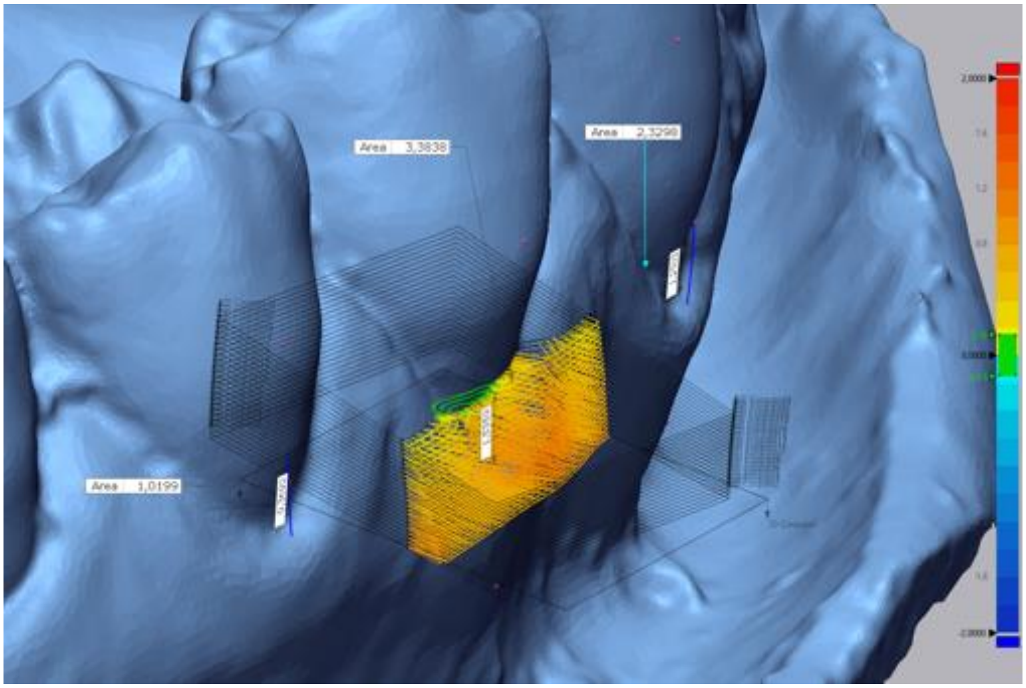

Figure 14 - Insertion of section plans perpendicular to ROI's entire length.

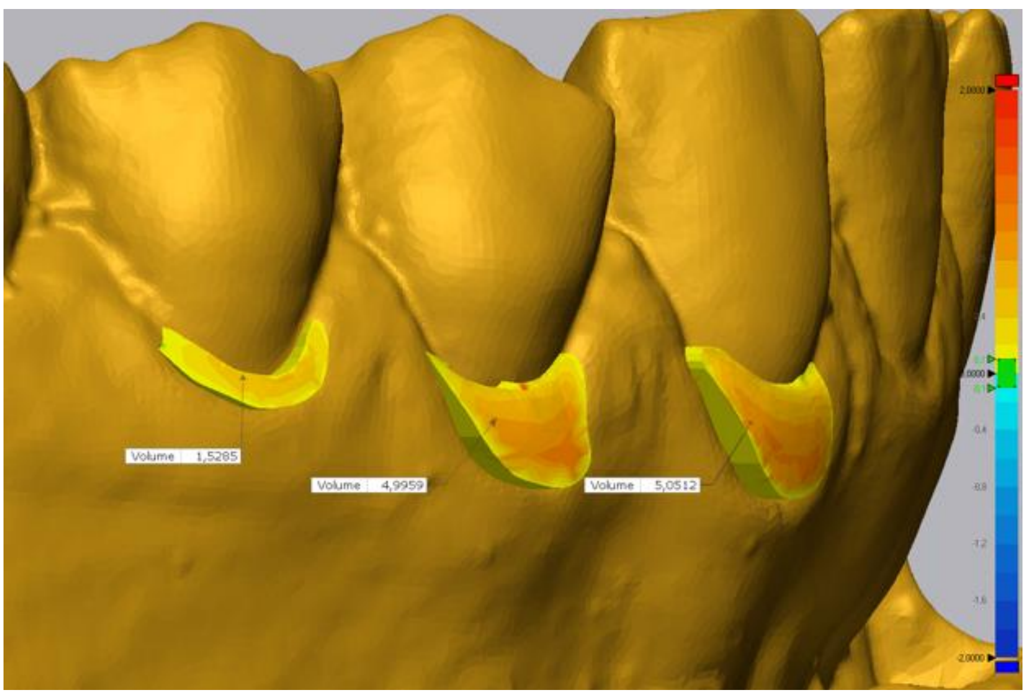

Figure 15 - The volume of tissue over the denuded root obtained after connective tissue graft between T0 (baseline) and T2 (6 months).

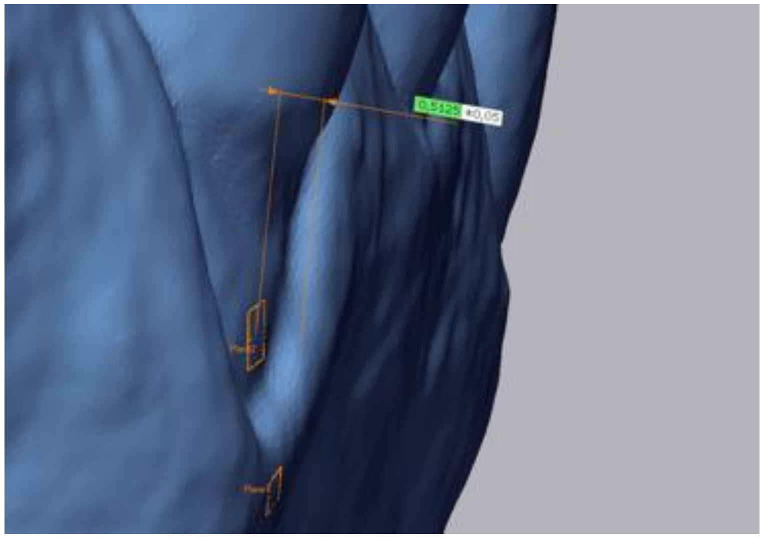

Figure 16 - Measuring distances between root surface and gingival margin.

III.8 Statistical analysis

A dedicated computer software (Statistical Package for the Social Sciences, v24.0; IBM, Armonk, NY, USA) was utilized to carry out data analysis. Descriptive statistics were performed using mean values, standard deviations, frequencies, and percentages. Mean values were calculated from the parameters measured at the recession sites at different time points. Normal distributions were checked by Shaphiro-Wilk Test, however, given the small sample size of each group, to compare techniques the Mann-Whitney test (non-parametric) was used instead of the paired T tests when the normal distribution was not verified. In each technique to compare the different times a t-test was applied when the test statistic would follow a normal distribution, or Wilcoxon signed-rank test when a normal distribution wasn't followed. A logistic model was calculated to model the probability of certain event to take place with the complete root coverage as the target variable and the mean marginal soft-tissue thickness at 6 months as the covariable (3DTHK).

All hypothesis tests were conducted at the 5% level of significance.

IV. RESULTS

Charts and casts from nineteen patients (4 males and 15 females) treated between December 2014 and January 2019 were included in this study. Their mean age was 26.4 (±7.9) years (age range, 17-48 years). One patient had recessions on anatomically separate locations of the maxilla, which resulted in two independent surgical sites. A total of 38 recessions were treated.

However, three patients from the Tunnel group did not attend the 6-month follow-up, and thus, only 32 defects were evaluated at 6 months, 15 tunnel and 17 VISTA. The TUN+CTG group contributed with 21 defects and the VISTA+CTG group with 17 defects. Details regarding patients' characteristics at baseline are shown in Tables 2, 3 and 4. No complications occurred in any included patients during the follow-up period.

PATIENT ID	AGE (YEARS)	GENDER	TOOTH	RECESSION	CEJ	STEP(+/-)
01	38	Male	16	RT1	**undetectable**	+
			15	RT1	**detectable**	+
			14	RT1	**undetectable**	+
02	26	Female	23	RT1	**detectable**	+
03	24	Female	13	RT1	**detectable**	-
			14	RT1	**detectable**	-
			16	RT1	**detectable**	-
04	24	Male	34	RT1	**detectable**	-
			35	RT1	**detectable**	-
05	23	Female	35	RT1	**undetectable**	+
06	21	Female	31	RT1	**detectable**	-
07	26	Female	14	RT1	**detectable**	-
			24	RT1	**detectable**	-
08	29	Female	34	RT1	**undetectable**	+
			35	RT1	**detectable**	-
			36	RT1	**undetectable**	+
09	20	Female	16	RT1	**detectable**	-
			15	RT1	**detectable**	-
			14	RT1	**detectable**	-
10	24	Female	24	RT1	**detectable**	-
			25	RT1	**detectable**	-

Table 2 - Patients' and site-specific characteristics for the tunneling technique. Recession: Cairo's recession classification; CEJ: cementoenamel junction; Class A: detectable CEJ; Class B: undetectable CEJ; Step: root surface concavity; +: presence of a cervical step

PATIENT ID	AGE (YEARS)	GENDER	TOOTH	RECESSION	CEJ	STEP (+/-)
11	23	Male	21	RT2	**detectable**	-
12	21	Male	41	RT2	**detectable**	-
13	17	Female	41	RT1	**detectable**	-
14	28	Female	43	RT1	**detectable**	-
15	42	Female	16	RT1	**undetectable**	+
			15	RT1	**undetectable**	+
			14	RT1	**detectable**	-
16	22	Female	31	RT2	**detectable**	-
			32	RT2	**detectable**	-
			41	RT2	**detectable**	-
			42	RT2	**detectable**	-
17	22	Female	31	RT1	**detectable**	-
18	48	Female	24	RT2	**undetectable**	+
			25	RT1	**detectable**	-
19	23	Female	43	RT1	**detectable**	-
			44	RT1	**detectable**	-
			45	RT1	**detectable**	-

Table 3 - Patients' and site-specific characteristics for the VISTA technique. Recession: Cairo's recession classification; CEJ: cementoenamel junction; Class A: detectable CEJ; Class B: undetectable CEJ; Step: root surface concavity; +: presence of a cervical step

Sociodemographic	All patients (n= 19)	Tunnel group (n=10)	Vista group (n=9)
	Mean (SD)	**Mean (SD)**	**Mean (SD)**
Age	26.37 ±7.93	25.5±5.08	27.33±10.51
Gender			
Male	21.05(%)	20(%)	22.22(%)
Female	78.95(%)	80(%)	79.78(%)
Type of teeth	**n=38**	**n=21**	**n=17**
Molars	13.16 (%)	21.74 (%)	5.88 (%)
Pre molars	52.63 (%)	66.7 (%)	35.29 (%)
Canines	10.53 (%)	9.52 (%)	11.76 (%)
Upper incisors	2.63 (%)	0 (%)	5.88 (%)
Lower incisors	21.05 (%)	4.76 (%)	41.17 (%)
Maxillary	50 (%)	66.7 (%)	29.41 (%)
Mandibular	50 (%)	33.33 (%)	70.59 (%)
Type of recession			
RT1	55.26 (%)	100 (%)	58.82 (%)
RT2	44.74 (%)	0 (%)	41.18 (%)
CEJ (A)	78.94 (%)	76.19 (%)	82.35 (%)
CEJ (B)	21.06 (%)	23.81 (%)	17.65 (%)
Cervical step (+)	26.32 (%)	33.33 (%)	17.65 (%)
Cervical step (-)	73.68 (%)	66.67 (%)	82.35 (%)

Table 4 - Description of the sample (n=19) and the treated recessions(n=38)

IV.1 Gingival recession characteristics

Recession depth, recession area, and gingival margin thickness are described in Table 5. In the TUN+CTG group, ten experimental sites were RT1: a total of 21 recessions, including three cases of single-defect recessions and seven multiple-defect recessions. Mean baseline recession depth was 1.38 ±0.29 mm. The VISTA+CTG group included RT1 and RT2 recession types: a total of 17 recessions, including five cases of single-defect recessions and four multiple-defect recessions. Mean baseline recession depth was 1.60 ±1.02 mm. A statistically significant reduction of the recession area was observed at both 3 months and 6 months ($p<0.001$ in both, Wilcoxon signed-rank test), independently of the technique used. No statistically significant changes were observed in the recession area between the 3- and 6-month follow-ups ($p=0.613$, Wilcoxon signed-rank test) on tunnel (p-value=0.317, Wilcoxon signed-rank test) and VISTA (p-value=0.893, Wilcoxon signed-rank test) respectively. No statistically significant changes were observed in the mean gingival thickness and maximum gingival thickness in 2D or 3D (2DTHK, 2DTHKMax, 3DTHK, 3DTHKMax).

	TUNNEL+CTG		VISTA+CTG		*P*-VALUE
	Recession Depth				
	n	mean±SD [mm]	n	mean±SD [mm]	
BASELINE	21	1.38±0.29	17	1.60±1.02	0.601
0-3 MONTHS	21	0.05±0.16	17	0.17±0.29	0.322
3-6 MONTHS	15	0.04±0.11	17	0.14±0.30	0.433
	Recession Area				
	n	mean±SD [mm^2]	n	mean±SD [mm^2]	
BASELINE	21	4.23±0.83	17	5.12±6.07	0.561
0-3 MONTHS	21	0.25±0.81	17	0.86±2.11	0.352
3-6 MONTHS	15	0.25±0.75	17	1.10±3.15	0.433
	Gingival Margin Thickness				
	n	mean±SD [mm]	n	mean±SD [mm]	
BASELINE	21	0.78±0.34	17	0.50±0.24	**0.000**
	2D mean gingival thickness (2DTHK)				
0-3 MONTHS	21	0.53±0.28	17	0.54±0.32	0.916
3-6 MONTHS	15	0.00±0.18	17	0.01±0.13	0.870
	2D maximum gingival thickness (2DTHK Max)				
	n	mean±SD [mm]		mean±SD [mm]	
0-3 MONTHS	21	1.20±0.39	17	1.18±0.48	0.902
3-6 MONTHS	15	0.43±0.43	17	0.43±0.26	0.982
	3D mean thickness of tissue over denuded root (3DTHK)				
	n	mean±SD [mm]	n	mean±SD [mm]	
3 MONTHS	21	0.34±0.13	17	0.32±0.16	0.693
6 MONTHS	15	0.34±0.14	17	0.33±0.16	0. 813
	3D maximum thickness of tissue over denuded root (3DTHK Max)				
	n	mean±SD [mm]		mean±SD [mm]	
3 MONTHS	21	1.19±0.36	17	1.20±0.46	0.968
6 MONTHS	15	1.10±0.34	17	1.29±0.47	0. 195

Table 5 - Recession depth and marginal soft-tissue thickness (2DTHK, 2DTHK Max, 3DTHK, 3DTHK Max mm) at baseline, 3 months, and 6 months

At the 3-month follow-up, root coverage was 95.6% (±14.5%) for the TUN+CTG Group and 88.9% (±20.5%) for the VISTA+CTG Group, with a recession reduction of 1.33 ± 0.86 mm and 1.42 ±0.92 mm, respectively (p=0.337). At the 6-month follow-up, root coverage was 96.5 ±10.4%) for the TUN+CTG Group and 93.9 ±10.3% for the VISTA+CTG Group, with a mean recession reduction of 1.35 ±0.85 mm and 1.45 ±0.82 mm, respectively (p=0.455). Complete root coverage was detected at 6 months in 86.7 ±0.4% of the TUN+CTG Group and 70.6 ±0.5% of the VISTA+CTG Group. No statistically significant differences were found between techniques (Table 6).

	BASELINE – 3 MONTHS			**BASELINE – 6 MONTHS**			**3 – 6 MONTHS**		
	Tunnel	**VISTA**	***p*-value**	**Tunnel**	**VISTA**	***p*-value**	***Tunnel***	***Vista***	***p*-value**
RECESSION DEPTH REDUCTION (MM)	1.33 ± 0.86	1.42 ± 0.92	0.931	1.35± 0.85	1.45± 0.82	0.706	0.03± 0.09	0.03± 0.18	0.180
% ROOT COVERAGE	95.6±14.5	88.9± 20.5	0.337	96.5± 10.4	93.9± 10.3	0.455	2.69± 7	4.97± 15.17	0.893
AREA REDUCTION (MM^2)	3.98± 2.49	4.26± 4.47	0.576	3.88± 2.29	4.02± 3.73	0.467	0.11± 0.42	-0.24± 1.09	0.317
% DEFECTS WITH COMPLETE ROOT COVERAGE	90.5± 0.3	70.5± 0.5	0.308	86.7± 0.4	70.6± 0.5	0.455			

Table 6 - Comparison of the Tunnel and VISTA Groups regarding recession depth reduction, percentage of root coverage, and percentage of defects with complete root coverage, at 3 and 6 months after surgery

There was no significant thickness gain (2DTHK) between the 3-month and 6-month follow-ups (p=0.778). Using the Mann-Whitney test to verify if the technique influences any variables, we found a statistically significant difference in the gingival margin thickness between the techniques (p<0.001), confirming the surgeon's technique choice according to the gingival biotype, where the tunnel technique was chosen for thicker biotypes (Figure 12). Even though VISTA technique shows a higher maximum thickness gained at 6 months there are no statistically significant differences (3DTHK Max) (p=0.056) (Figure 18).

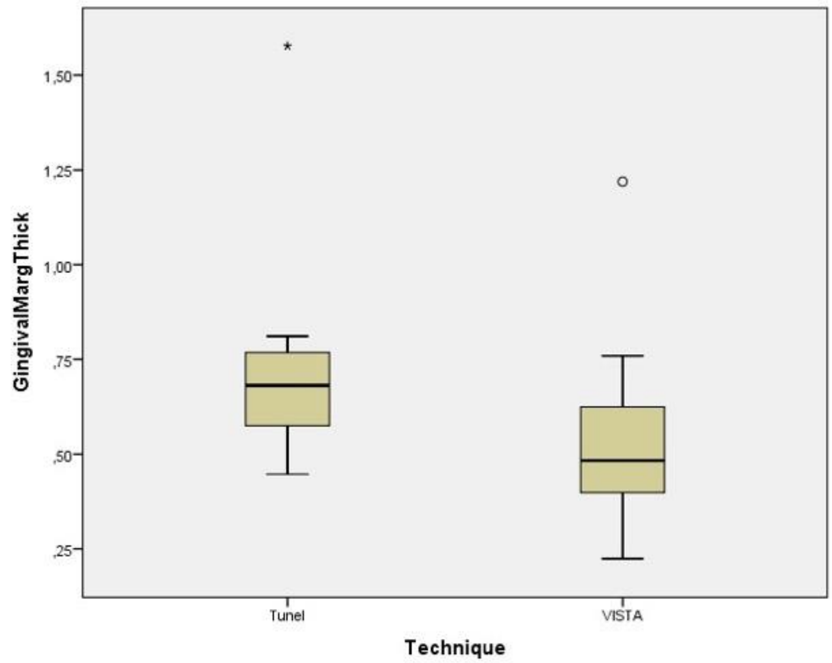

Figure 17 - Box-plot showing the gingival margin thickness (mean and interquartile range) of patients treated with the tunnel vs. VISTA techniques. Symbols (star and circle) indicate outliers of the study sample.

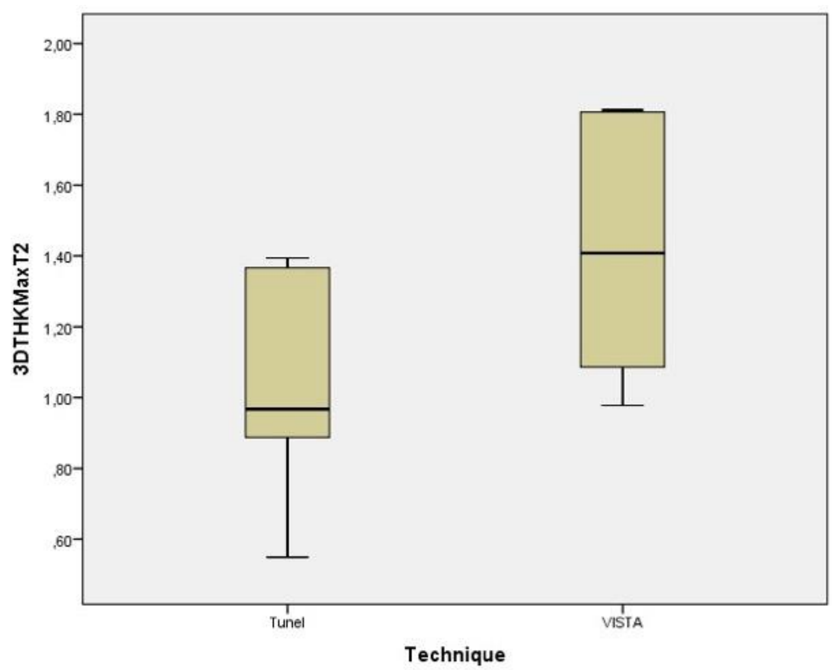

Figure 18 - Box-plot showing 3DTHKMax T2 (mean and interquartile range) for patients treated with the tunnel vs. VISTA techniques

The measured data indicate a certain soft-tissue thickness above which no further benefit was obtained in terms of surgical outcome. A logistic model was calculated with the complete root coverage as the target variable and the mean marginal soft-tissue thickness at 6 months as the covariable (3DTHK). This analysis indicated that a mean 3DTHK of 0.35 mm was necessary to predict a complete root coverage with 95% confidence.

IV.2 Correlation between gingival margin thickness, papilla height, recession reduction area, and root coverage

A positive Pearson's correlation was found between the gingival margin thickness and the recession reduction area at the 6-month follow-up ($r=-0.407$; $p=0.025$). On the other hand, the gingival margin thickness was not correlated with Cairo's recession classification at 6 months ($p=0.77$) or root coverage at both 3 months ($p=0.560$) and 6 months ($p=0.531$). (Table 7a and 7b)

		GINGIVAL MARGTHICK	% ROOT COVERAGE T1	% ROOT COVERAGE T2	VOLUMET1	VOLUMET2	AREA REDUCTION T1T2	AREA REDUCTION T0T1	AREA REDUCTION T0T2
GINGIVALMARGTHICK	Pearson Correlation	1	0,047	-0,063	0,280	0,296	,396*	0,292	-,396*
	Sig. (bilateral)		0,777	0,731	0,089	0,100	0,025	0,075	0,025
	N	38	38	32	38	32	32	38	32
% ROOT COVERAGE T1	Pearson Correlation	0,047	1	,821**	0,153	0,222	0,144	0,122	-0,144
	Sig. (bilateral)	0,777		0,000	0,358	0,222	0,430	0,465	0,430
	N	38	38	32	38	32	32	38	32
% ROOT COVERAGE T2	Pearson Correlation	-0,063	,821**	1	-0,065	-0,006	-0,076	-0,145	0,076
	Sig. (bilateral)	0,731	0,000		0,722	0,972	0,678	0,427	0,678
	N	32	32	32	32	32	32	32	32
VOLUMET1	Pearson Correlation	0,280	0,153	-0,065	1	,967**	,866**	,856**	-,866**
	Sig. (bilateral)	0,089	0,358	0,722		0,000	0,000	0,000	0,000
	N	38	38	32	38	32	32	38	32
VOLUMET2	Pearson Correlation	0,296	0,222	-0,006	,967**	1	,900**	,909**	-,900**
	Sig. (bilateral)	0,100	0,222	0,972	0,000		0,000	0,000	0,000
	N	32	32	32	32	32	32	32	32
AREA REDUCTION T1T2	Pearson Correlation	,396*	0,144	-0,076	,866**	,900**	1	,977**	-1,000**
	Sig. (bilateral)	0,025	0,430	0,678	0,000	0,000		0,000	0,000
	N	32	32	32	32	32	32	32	32
AREA REDUCTION T0T1	Pearson Correlation	0,292	0,122	-0,145	,856**	,909**	,977**	1	-,977**
	Sig. (bilateral)	0,075	0,465	0,427	0,000	0,000	0,000		0,000
	N	38	38	32	38	32	32	38	32
AREA REDUCTION T0T2	Pearson Correlation	-,396*	-0,144	0,076	-,866**	-,900**	-1,000**	-,977**	1
	Sig. (bilateral)	0,025	0,430	0,678	0,000	0,000	0,000	0,000	
	N	32	32	32	32	32	32	32	32
2DTHK T0-T1	Pearson Correlation	0,028	,340*	0,230	,719**	,700**	,551**	,518**	-,551**
	Sig. (bilateral)	0,866	0,037	0,206	0,000	0,000	0,001	0,001	0,001
	N	38	38	32	38	32	32	38	32
2DTHK T1-T2	Pearson Correlation	-0,149	0,041	-0,104	-0,017	0,179	0,181	0,133	-0,181
	Sig. (bilateral)	0,415	0,825	0,573	0,928	0,327	0,323	0,467	0,323
	N	32	32	32	32	32	32	32	32
2DTHK T0-T2	Pearson Correlation	0,037	,373*	0,173	,693**	,759**	,616**	,592**	-,616**
	Sig. (bilateral)	0,841	0,036	0,344	0,000	0,000	0,000	0,000	0,000
	N	32	32	32	32	32	32	32	32
3DTHK MAX T1	Pearson Correlation	0,295	0,142	0,026	,679**	,642**	,604**	,556**	-,604**
	Sig. (bilateral)	0,072	0,395	0,889	0,000	0,000	0,000	0,000	0,000
	N	38	38	32	38	32	32	38	32
3DTHK T0T1	Pearson Correlation	0,285	,365*	0,194	,879**	,883**	,737**	,688**	-,737**
	Sig. (bilateral)	0,083	0,024	0,286	0,000	0,000	0,000	0,000	0,000
	N	38	38	32	38	32	32	38	32
3DTHK MAX T2	Pearson Correlation	0,088	0,322	0,223	,681**	,692**	,570**	,568**	-,570**
	Sig. (bilateral)	0,631	0,072	0,220	0,000	0,000	0,001	0,001	0,000
	N	32	32	32	32	32	32	32	32
3DTHK T0T2	Pearson Correlation	0,185	,410*	0,212	,798**	,871**	,764**	,727**	-,764**
	Sig. (bilateral)	0,310	0,020	0,244	0,000	0,000	0,000	0,000	0,000
	N	32	32	32	32	32	32	32	32

Table 7(a) - Correlations Table ***(*. correlation is significant at the 0.05 levels)***

		2DTHK T0-T1	2DTHK T1-T2	2DTHK T0-T2	3DTHK MAX T1	3DTHK T0T1	3DTHK MAX T2	3DTHK T0T2
GINGIVALMARGTHICK	Pearson Correlation	0,028	-0,149	0,037	0,295	0,285	0,088	0,185
	Sig. (bilateral)	0,866	0,415	0,841	0,072	0,083	0,631	0,310
	N	38	32	32	38	38	32	32
% ROOT COVERAGE T1	Pearson Correlation	,340*	0,041	,373*	0,142	,365*	0,322	,410*
	Sig. (bilateral)	0,037	0,825	0,036	0,395	0,024	0,072	0,020
	N	38	32	32	38	38	32	32
% ROOT COVERAGE T2	Pearson Correlation	0,230	-0,104	0,173	0,026	0,194	0,223	0,212
	Sig. (bilateral)	0,206	0,573	0,344	0,889	0,286	0,220	0,244
	N	32	32	32	32	32	32	32
VOLUMET1	Pearson Correlation	,719**	-0,017	,693**	,679**	,879**	,681**	,798**
	Sig. (bilateral)	0,000	0,928	0,000	0,000	0,000	0,000	0,000
	N	38	32	32	38	38	32	32
VOLUMET2	Pearson Correlation	,700**	0,179	,759**	,642**	,883**	,692**	,871**
	Sig. (bilateral)	0,000	0,327	0,000	0,000	0,000	0,000	0,000
	N	32	32	32	32	32	32	32
AREA REDUCTION T1T2	Pearson Correlation	,551**	0,181	,616**	,604**	,737**	,570**	,764**
	Sig. (bilateral)	0,001	0,323	0,000	0,000	0,000	0,001	0,000
	N	32	32	32	32	32	32	32
AREA REDUCTION T0T1	Pearson Correlation	,518**	0,133	,592**	,556**	,688**	,568**	,727**
	Sig. (bilateral)	0,001	0,467	0,000	0,000	0,000	0,001	0,000
	N	38	32	32	38	38	32	32
AREA REDUCTION T0T2	Pearson Correlation	-,551**	-0,181	-,616**	-,604**	-,737**	-,570**	-,764**
	Sig. (bilateral)	0,001	0,323	0,000	0,000	0,000	0,001	0,000
	N	32	32	32	32	32	32	32
2DTHK T0-T1	Pearson Correlation	1	-0,164	,886**	,538**	,853**	,688**	,789**
	Sig. (bilateral)		0,369	0,000	0,000	0,000	0,000	0,000
	N	38	32	32	38	38	32	32
2DTHK T1-T2	Pearson Correlation	-0,164	1	0,312	-0,222	-0,043	-0,005	0,274
	Sig. (bilateral)	0,369		0,082	0,221	0,814	0,980	0,129
	N	32	32	32	32	32	32	32
2DTHK T0-T2	Pearson Correlation	,886**	0,312	1	,432*	,824**	,661**	,888**
	Sig. (bilateral)	0,000	0,082		0,014	0,000	0,000	0,000
	N	32	32	32	32	32	32	32
3DTHK MAX T1	Pearson Correlation	,538**	-0,222	,432*	1	,668**	,657**	,544**
	Sig. (bilateral)	0,000	0,221	0,014		0,000	0,000	0,001
	N	38	32	32	38	38	32	32
3DTHK T0T1	Pearson Correlation	,853**	-0,043	,824**	,668**	1	,708**	,894**
	Sig. (bilateral)	0,000	0,814	0,000	0,000		0,000	0,000
	N	38	32	32	38	38	32	32
3DTHK MAX T2	Pearson Correlation	,688**	-0,005	,661**	,657**	,708**	1	,675**
	Sig. (bilateral)	0,000	0,980	0,000	0,000	0,000		0,000
	N	32	32	32	32	32	32	32
3DTHK T0T2	Pearson Correlation	,789**	0,274	,888**	,544**	,894**	,675**	1
	Sig. (bilateral)	0,000	0,129	0,000	0,001	0,000	0,000	
	N	32	32	32	32	32	32	32

Table 8(b) - Correlations Table ***(*. correlation is significant at the 0.05 levels)***

The papilla height was correlated with the recession reduction area at 6 months (r=-0.636; p<0.001) and 3 months (r = -0.626; p<0.001). However, the papilla height was not correlated with Cairo's recession classification (p=0.531) or the technique (p=0.549). Also, no correlation was found between the papilla height and root coverage at both 3 months (p=0.698) and 6 months (p=0.315). (Table 8)

CORRELATIONS TABLE FOR PAPILLA HEIGHT

		Papilla Height	% ROOT COVERAGE T1	% ROOT COVERAGE T2	Area reduction T1T2	Area reduction T0T1	Area reduction T0T2
PAPILLA HEIGHT	Pearson Correlation	1	0,065	-0,183	,636**	,626**	-,636**
	Sig. (bilateral)		0,698	0,315	0,000	0,000	0,000
	N	38	38	32	32	38	32
% ROOT COVERAGE T1	Pearson Correlation	0,065	1	,821**	0,144	0,122	-0,144
	Sig. (bilateral)	0,698		0,000	0,430	0,465	0,430
	N	38	38	32	32	38	32
% ROOT COVERAGE T2	Pearson Correlation	-0,183	,821**	1	-0,076	-0,145	0,076
	Sig. (bilateral)	0,315	0,000		0,678	0,427	0,678
	N	32	32	32	32	32	32
AREA REDUCTION T1T2	Pearson Correlation	,636**	0,144	-0,076	1	,977**	-1,000**
	Sig. (bilateral)	0,000	0,430	0,678		0,000	0,000
	N	32	32	32	32	32	32
AREA REDUCTION T0T1	Pearson Correlation	,626**	0,122	-0,145	,977**	1	-,977**
	Sig. (bilateral)	0,000	0,465	0,427	0,000		0,000
	N	38	38	32	32	38	32
AREA REDUCTION T0T2	Pearson Correlation	-,636**	-0,144	0,076	-1,000**	-,977**	1
	Sig. (bilateral)	0,000	0,430	0,678	0,000	0,000	
	N	32	32	32	32	32	32

(**. CORRELATION IS SIGNIFICANT AT THE 0.01 LEVELS)

Table 9- Correlations for Papilla Height

IV.3 Healing dynamics of treated sites

The results of the volumetric assessments performed are shown in Table 9.

The soft tissue gained at 3 months was regarded as the standard value of soft-tissue augmentation, the grafted sites showed a mean gain at 3 months of 4.45 ±3.42 mm^3 in the TUN+CTG Group and 5.27 ±5.79 mm^3 in the VISTA+CTG Group (p=0.772). At 6 months, the treated sites showed a mean gain of 4.72 ±3.88 mm^3 in the TUN+CTG Group and 5.43 ±5.21 mm^3 in the VISTA+CTG Group (p=1.000). From T1 to T2 (6 months), there was a mean volume increase of 13.2 ±5%, where the TUN+CTG Group showed a higher mean volume increase of 18.9 ±58.4% and the VISTA+CTG Group of 8.1 ±53.1% (p=0.710).

		VOLUME ALTERATIONS AT 3 MONTHS		VOLUME ALTERATIONS AT 6 MONTHS	
PATIENT ID	**Tooth**	**Absolute (mm^3)**	**Relative(%)**	**Absolute(mm^3)**	**Relative(%)**
01	16	2.78	100	2.79	0.41
	15	2.51	100	2.95	17.66
	14	4.43	100	4.86	9.67
02	23	9.56	100	11.30	18.17
03	13	6.92	100	7.86	13.69
	14	2.92	100	4.73	62.23
	16	1.45	100	2.01	38.49
04	34	4.57	100		
	35	2.75	100		
05	35	5.50	100		
06	31	0.28	100	0.76	175.97
07	14	2.67	100	2.92	9.09
	24	0.80	100	1.51	90.03
08	34	7.49	100	6.93	-7.46
	35	6.45	100	5.22	-19.09
	36	15.40	100	14.04	-8.81
09	16	3.11	100		
	15	1.94	100		
	14	5.41	100		
10	24	4.16	100	2.21	-46.75
	25	2.40	100	0.72	-70.05
11	21	22.41	100	18.02	-19.59
12	41	8.80	100	9.18	4.38
13	41	6.03	100	5.71	-5.26
14	43	4.44	100	6.09	37.13
15	16	11.18	100	13.78	23.23
	15	5.92	100	6.15	3.80
	14	1.70	100	1.93	13.37
16	31	2.22	100	2.59	16.48
	32	0.74	100	1.88	153.82
	41	0.66	100	0.20	-69.11
	42	0.02	100	0.00	-97.01
17	31	0.74	100	1.23	66.18
18	24	12.30	100	12.32	0.21
	25	1.02	100	1.20	17.29
19	43	5.05	100	5.85	15.74
	44	4.86	100	5.00	2.84
	45	1.53	100	1.15	-25.08
MEAN		**4.82±4.58**	**100%±0**	**5.10±4.58**	**13.18%±54.97**

Table 10 - Descriptive statistics with absolute (mm3) and relative (%) values of volume alterations following CT grafting at both the VISTA and TUN groups.

The clinical outcomes can be observed in Figure 19, Figure 20, Figure 21 and Figure 22.

Figure 19 - Baseline (VISTA technique)

Figure 20 - 6 months results (VISTA technique)

Figure 21 - Baseline (Tunnel Technique)

Figure 22 - 6 months results (Tunnel technique)

IV.4 Validation of the Volumetric changes after periodontal plastic surgery

This method was validated one year after the initial measurements, the author and an independent investigator made three distinct measurements of the following variables Gingival Margin thickness, Volume T2, 3DTHK T1, that represent the innovation of this research, the results of Intra and Inter class Correlation Coefficient (ICC) were calculated using SPSS. (Table 10 and 11)

Gingival Margin thickness			Volume T2			3DTHK T1		
1	**2**	3	**1**	**2**	**3**	**1**	**2**	**3**
0,5125	0,4724	0,5512	11,2959	10,938	11,452	0,4693	0,4227	0,4457

Table 11 – Repeated measurements one year after initial measurements

Intra class Correlation Coefficient estimates, and their 95% confident intervals were calculated using SPSS statistical package version 24 based on a mean-rating (k = 3), absolute-agreement, 2-way mixed-effects model. The intra-rater reliability of 0.999 indicates an excellent reliability.

	Gingival Margin thickness			Volume T2			3DTHK T1		
Measurements	1	2	3	1	2	3	1	2	3
Rater 1	0,5125	0,4724	0,5512	11,2959	10,938	11,452	0,4693	0,4227	0,4457
Rater 2	0,4454	0,4059	0,4988	11,653	11,067	11,331	0,4845	0,4987	0,5038

Table 12 - Repeated Measurements one year after initial measurements by a different clinician

Inter class correlation coefficient estimates and their 95% confident intervals were calculated using SPSS statistical package version 24 based on a mean-rating (k = 3), absolute-agreement, 2-way mixed-effects model. The inter-rater reliability of 0.999 indicates an excellent reliability.

The superimposition was performed, and the results obtained showed mostly green surface which indicates both the study model and reference model corresponded to one another. Using the best fit algorithm, we obtained a more precise alignment minimizing the differences between the surfaces. This precision is translated by the Root mean square value (RMS) that shows how accurate the process is. A higher calculated RMS value indicated a large error, i.e., the difference in the attributes between reference and measurement data. RMS mean value for the 0-3 months scans was 0,14 (±0.05) mm and 3 to 6 months was 0,12 (±0.03) mm as shown on Table 12.

	PATIENT ID	RMS BEST FIT ALIGNMENT	
		0-3 Months (mm)	3-6 Months (mm)
TUNEL	1	0,17	0,1195
	2	0,1244	0,2015
	3	0,1179	0,113
	4	0,138	NC
	5	0,0935	NC
	6	0,1187	0,0871
	7	0,0804	0,0682
	8	0,0778	0,1067
	9	0,2601	NC
VISTA	10	0,146	0,1489
	11	0,1825	0,1016
	12	0,1283	0,0899
	13	0,1755	0,0955
	14	0,0875	0,0964
	15	0,1755	0,1037
	16	0,2484	0,1438
	17	0,106	0,1034
	18	0,1253	0,1417
	19	0,1088	0,1184
	Mean	**0,140±0.051 mm**	**0,115±0.031 mm**

Table 13-Alignment accuracy, root mean square value (RMS), (NC) No show

V DISCUSSION

The digital evaluation protocol presented in this research is innovative as it adapts commonly used measurement tools of a computer-aided-design software, available mainly for engineering issues, for periodontology research in a way that was not previously published, particularly in the analysis of variables like gingival margin thickness. In this research, a highly precise measurement method was used to evaluate the clinical outcomes of two different periodontal plastic surgical techniques in the treatment of gingival recessions. Within the limitations of this research, particularly related to the limited sample size, the null hypothesis was not rejected, since no statistically significant differences were found in the clinical outcomes.

This research was done following the normal clinical environment of the University Dental Clinic. There was a full control of techniques and materials available for the surgical procedure to achieve the expected treatment success. The surgeon (T.M) had no knowledge that the presented research was being developed. All the impressions were made by an independent investigator in a conventional way with alginate and cast models were fabricated, as they were the commonly available dental materials. Although alginate has the lowest accuracy of all conventional impression materials , the use of regular casts that could include artifacts as those occurring in everyday practice offers a true representation of current clinical conditions(76). Naturally, it could also account for part of the differences detected by different techniques, but it would do so in all cases, since the same methodology was used in every single case. It would be preferable to obtain the data directly with an IOS, to avoid a possible bias of conventional impression materials, but the availability of the IOS in the university dental clinic was not possible at all times, reason why the methodology described before was adopted. Although a systematic review (77) that assessed the validity of intra-arch dimensional measurements made from laser-scanned digital dental models in comparison with measurements directly obtained from the original plaster casts (gold standard), concluded that the precision and accuracy (reliability and validity) of digital models obtained by scanning plaster models are clinically acceptable as a diagnostic tool. Also the Best Fit Alignment deviation is within the values of other studies in the literature where the accuracy of the different alignment techniques are evaluated and their impact on measurement metrics, showing a 130µm (±26µm) translation error for the best fit technique.(77)

The use of intraoral scanners goes back to 1987 known as the Chairside Economical Restoration of Esthetic Ceramics(78). They were firstly used to measure alveolar ridge defects(66). Since then, their use has been successfully adopted to mucogingival surgery(16,19,21,74). The intra-oral scanner used to do the 3D reconstruction of the cast models in the University Dental Clinic is from the year 2015. Although there are currently new IOS with better characteristics, this scanner allows the capture of a precise image in small dimension areas as those that we have done(79,80). It is not a IOS to perform a full-arch digitalization(81). There are analogue methods reported in dental literature to do these types of measurements such as direct soft/hard tissue measurements with probes and calipers. (26,28,78) However, these are invasive procedures that require some type of clinical/surgical intervention, and the measurements that can be obtained with mechanical clinical instruments are far less precise than current digital methods as present here. It is easy to understand that a 3D volumetric analysis with digital software allows to obtain measurements in any/every area, without the need to have the patient in the dental chair. The patient only needs to be at the dental appointment to have an intra-oral scan, and all the 3D volumetric analyses can be done by the clinician at a later time. Of course, this cannot be achieved with mechanical clinical instruments because the clinician has to do several clinical observations, which is time consuming, and it would require to puncture the periodontal area several times with all its invasiveness and, as stated before, less precision.

Transgingival probing approaches have been frequently utilized for evaluating gain in gingival thickness following root coverage procedures in natural dentition, but these methods, are all considered invasive to the patient, CBCT has the drawback of ionizing radiation.(52)

Considering the surgery techniques in evaluation, both showed recession reduction and complete root coverage. TUN+CTG and VISTA+CTG had similar root coverage results VISTA+CTG (95.6% (±14.5%) and 88.9% (±20.5%), respectively), with no statistically significant differences. Our study showed a mean root coverage superior to the latest systematic review and it can be explained by the microsurgical approach and the split-thickness used in the TUN+CTG(82). Complete root coverage at 6 months was also highest in the TUN+CTG Group with 86.7% (±0.4%) than the VISTA+CTG Group, with 70.6% (±0.5%). However, both these differences might be due to all Cairo RT2 recessions being in the VISTA+CTG group, reducing the percentage of root coverage in this group. On the other hand, the higher recession reduction in the VISTA+CTG group of 1.42 (±0.92) mm vs. 1.33 (±0.86) mm in the TUN+CTG group is probably explained by the deeper recessions in the VISTA+CTG group.(23)

The flap design is a key factor in the outcomes following root coverage and is considered a prognostic factor in the treatment of gingival recession defects(17,83,84). Several studies have correlated greater flap thickness to better clinical outcomes after root coverage(85). Also, a preoperative gingival marginal thickness greater than 1 mm correlates with a higher percentage of root coverage.(21) In our study, we described a unique non-invasive methodology to determine the pre-surgical gingival margin thickness. To the best of our knowledge, a similar metrology technique has not been previously reported. The precise results obtained found a strong correlation with recession area reduction, which is in line with the literature. Gingival margin thickness can be used as a noninvasive surrogate for flap thickness measurement.(86)

Soft-tissue grafting turned out to be more pertinent in periodontal plastic surgeries as a predictor for soft-tissue stability.(41,87) The percentage of root coverage attained in this study is likely related to the coronal displacement of the gingival margins past the CEJ (74,88,89) and to the fact that no vertical incisions were done, which enhances the vascular supply of pedicle flaps.(90)

The correlation between marginal soft-tissue thickness and root coverage stability is still debated because not many researchers have actually aimed to assess the soft-tissue thickness over the exposed root surface(16). It is believed that any increase in thickness will show long-term stability(16,91). However, by comparing baseline and follow-up soft-tissue profiles and volume differences, we can determine the thickness of the marginal soft tissues that have been obtained over the denuded root. Evidence has shown that combining the procedure with an autologous CTG is the most effective and predictable surgical approach for covering gingival recession defects.(91–93)

The use of a de-epithelialized graft allows integration in the graft the connective tissue adjacent to the epithelium, which is denser, firmer, more stable, and supposedly more suitable for root coverage(35,94). These types of CTGs demonstrate a greater increase of gingival thickness at the buccal aspect than subepithelial CTGs that lose a significant part of their thickness during the healing phase(94). In our study, the amount of thickness gain needed for complete root coverage diverged considerably from the results by Zuhr et al(19) because of the type of connective tissue harvested. We used a de-epithelialized graft, which tends to be more stable in terms of contraction than subepithelial grafts.(94) The different measuring techniques could also explain such a difference.

In our study, the creeping attachment phenomenon happened due to increased volumetric alterations after 6 months, which disagrees with others papers published(16,19). These dissimilarities are probably explained by the different types of connective tissue graft used in this study. Both cited papers(16,19) indicate a contraction of the graft, around two-thirds of the augmented volume was maintained after 12 months and soft-tissue healing was accomplished at 6 months. In our research, using a de-epithelized graft, we saw a mean volume increase at 6 months 13.2% (±55%). In the paper by Rebele et al. they showed 26% percent contraction of the grafted area at 3 months and a 37% contraction of the grafted area at 6 months.

Our study's measured data indicated a certain soft-tissue thickness above which no further benefit was seen regarding the surgical outcome. Therefore, a logistic model was calculated with the complete root coverage as the target variable and the mean marginal soft-tissue thickness at 6 months as the covariable (3DTHK). This analysis indicated that a mean 3DTHK of 0.35 mm had to be maintained for predicting a complete root coverage with a confidence of 95%. This finding is confirmed by some recommendations on clinical decision making that incentivize the usage of thin CTGs for root coverage.(91,95)

The reduced thickness and the apical-coronal dimension of the graft, together with its positioning apical to the CEJ, minimized the hindering of the vascularization from the receiving connective tissue bed to the coronally advanced flap. The bigger and thicker the graft, the greater the barrier, and the higher risk of dehiscence and consequent graft exposure.(21) The reduced thickness and the apical-coronal dimension of the connective tissue graft also facilitate the graft coverage by the tunnel or VISTA approaches, improving the aesthetic outcome, allowing the covering flap to remain stable in the coronal position, hiding the unaesthetic white-scar appearance of the graft, and providing the treated area with the same gingival margin originally present apical to the recession defect.

Volume changes and the healing process seems to be accomplished after 6 months(16). We present new data indicating that grafted sites with de-epithelized grafts will experience a volume increase up to 6 months. However, due to this study's limitations, a higher patient number would be necessary to draw any valid conclusions. We now intend to conduct a 2-year follow-up to evaluate the stability of these types of grafts. We recommend small-sized and thin grafts because these could enhance the nutritional exchange between the recipient site, graft, and covering flap.

The present retrospective study has some limitations, including being retrospective, a small sample size, having no randomization of treatments, and the inability to perform direct digital impressions. Also, an esthetic evaluation could not be performed because of the retrospective nature of the analysis. This study is also limited in comparing the two techniques because thin biotypes and RT2 were treated with VISTA technique, being the most suitable technique to avoid the risk of perforation or trauma of the sulcular tissues, papilla laceration, reduced coronal mobilization of the flap, and reduced papilla mobilization. The number of RT2 was higher in the VISTA group and could therefore influence the results.

Nonetheless, the used measuring method gives new insights in high-precision outcome evaluation after surgical recession treatment, ensuring the same region of interest is analyzed on all post-surgical time points, with an insignificant level of error and high reliability(65). A new non-invasive method to measure the gingival marginal thickness was developed, and new outcome parameters that are not easily measured in the clinical setting were examined in this study. In future studies, a randomized control clinical trial should be done to compare both techniques digitally by analyzing the outcomes, using recently developed intra oral scanners, directly without conventional impressions. The technique currently considered as the gold standard is clearly invasive, too dependent on the individual operator, and calibrated in millimeters, unable to measure microns and gingival volume increase.(65)

We characterized the healing dynamics of the grafted sites and assessed the influence of the thickness in the newly created soft tissues on the outcome of the surgical techniques. This measurement technology allows for an unprecedented precision in linear measurements as in volumetric measurements and influences the study's outcomes. It cannot be compared with studies where the measurements were conducted using a periodontal probe, where a rounding error must be accepted.

The digital protocol here described can be applied in future research since it has several advantages: non-invasive, easy, and precise. One property of a new method of gingival volume assessment should be the discriminative capacity of distinct situations, not only in pre-post assessment but also between comparable patients that were treated with distinct techniques. This non-invasive method has demonstrated to be able to capture significant pre-post difference and clinically relevant trends between both surgical techniques. Furthermore, it follows the evolution of digital technology in Dentistry, and results can be even more precise in a near future due to new IOS technologies being introduced by dental manufacturers.

V CONCLUSION

In summary, the applied methodology offers new insights in evaluating the outcomes after surgical recession treatment, with the highest precision and accuracy. Both techniques provided a reduction in gingival recession and an increase in gingival thickness, with no statistically significant differences. This promising method, which has excellent reliability, could easily be recognized as the new gold standard for non-invasive evaluations.

VI LIMITATIONS AND FUTURE LINES OF INVESTIGATION

VII.1 Limitations

One of the main drawbacks of this study was the retrospective nature, a small sample size and no randomization of treatments.

Another limitation for comparing the two techniques was the choice done by the surgeon to treat thin biotypes and RT2 were treated with VISTA technique, being the most suitable to technique to avoid complications but could bias the results.

The long-term stability regarding the increased gingival thickness is hypothetical.

VII.2 Future Lines of investigation

This study uses a non-invasive 3D digital measuring methods to evaluate the healing dynamics at CT-grafted sites using an innovative new measuring method, promising to make another small step towards further understanding in this field.

It is beyond all doubt that more transparency and understanding in this context will substantially influence future research and clinical developments, in particular against the background of an ever-increasing field of biomaterial science, which continuously launches improved products that aim to substitute the use of autologous grafts. As harvesting of a CTG adds additional morbidity to any surgical root coverage procedure, it is necessary to further clarify the clinical relevance and long-term benefit of the combined procedure on a scientific basis.

VII.2.1 Healing Dynamics

This new technique can be used to assess the healing dynamics of the palate after connective tissue grafting.

It could be useful to conduct a randomized controlled trial to assess the benefit of some products on palate healing such as PRF, surgical glue, stent, collagen plugs.

Using an intra oral scanner to precisely obtain the volume of graft removed and comparison in the different time points with the different techniques.

This way we could inform our patients objectively what technique will get the faster and better healing.

VII.2.2 Soft tissue graft Stability

The soft tissue contraction or growth can be evaluated when in use with dental implants, as most of publications show a contraction of the graft in the first months but a long-term follow-up of 5 years or more might show a soft a tissue growth, consistent with clinical experience.

It could be useful to conduct a prospective clinical trial to evaluate the effect of tuberosity grafts on the contour of the alveolar crest simultaneous with implant placement.

Annual controls after the first year (first year: 1 week, 6 weeks, 3 months and 6 months).

This way we could inform our patients objectively that the soft tissue augmentation simultaneous with implant placement is a safe predictable and long term stable when compared to bone contour augmentation with less complications.

VII.2.3 Effect of customized healing abutments

This method can be used in the study of the effect of customized healing abutments compared to standard healing abutments in a randomized controlled trial. Our group has recently published a one-year prospective study on this effect.(96)

VII.2.4 Creeping attachment effect

This new technique can be used to assess the healing dynamics of connective tissue grafting objectively quantifying this clinical effect observed over time. It could be useful to conduct a prospective clinical trial to evaluate the effect of free gingival grafts. Annual controls after the first year (first year: 1 week, 6 weeks, 3 months and 6 months)

VII.2.5 Non-Invasive method to determine marginal gingival thickness

Marginal gingival thickness determination is an invasive and difficult procedure. Using this non-invasive technology, a correlation could be established between the most used method to determine gingival biotype and accurate marginal thickness. A gingival marginal thickness characterization study could be performed for a specific population.

VII.2.7 Immediate implants in maxillary region

To study the effects of immediate implant placement in the maxillary region with a prospective study. Our group has already published a one-year prospective study on this effect. (97)

VIII.2.7 Root surface defects and concavities

No digital evaluation of root surface concavity was performed in the reviewed studies despite its importance, stated in the latest review(61) . Computer-aided 3D image analysis facilitates evaluation of morphology of root surface defects. A prospective study would be useful to study the effect of these defects on root coverage.

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IX APPENDICES

Publications related to this evaluation technique

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A new digital evaluation protocol applied in a retrospective analysis of periodontal plastic surgery of gingival recessions

Tiago Marques[1,4,5,6]✉, N. M. Santos[1,5], Joana Fialho[2], J. Montero[3] & A. Correia[1,5]

This research aimed to develop a new digital evaluation protocol to objectively quantify the volumetric changes of root coverage periodontal plastic surgery when combined with connective tissue graft. Consecutive patients with Cairo recession type 1 (RT1) or Cairo recession type 2 (RT2) were treated. Accurate study models obtained at baseline and follow-ups were optically scanned. Healing dynamics were measured by calculating volume differences between time points. Nineteen patients were treated between December 2014 and January 2019. At 3-month follow-up, root coverage was 95.6% (± 14.5%) with tunnel and connective tissue graft (TUN + CTG) technique, and 88.9% (± 20.5%) with the vestibular incision subperiosteal tunnel access and connective tissue graft (VISTA + CTG) technique. Recession decreased 1.33 (± 0.86) mm and 1.42 (± 0.92) mm, respectively (p = 0.337). At 6-month follow-up, root coverage was 96.5% (± 10.4%) with the TUN + CTG and 93.9% (± 10.3%) with the VISTA + CTG. Recession decreased 1.35 (± 0.85) mm and 1.45 (± 0.82) mm, respectively (p = 0.455). Complete root coverage was achieved in 86.7% (± 0.4%) with TUN + CTG and 70.6% (± 0.5%) with VISTA + CTG. No statistically significant differences were found between techniques. The digital protocol presented proved to be a non-invasive technique for accurate measurements of clinical outcomes. Both techniques reduce gingival recessions, with no statistically significant differences.

The development of intra-oral and laboratory scanners associated with 3D analysis software make it possible to evaluate volumetric changes in the hard and soft tissues of the oral cavity[1]. This technology was first described to measure in vitro alveolar ridge defects. It has been adopted in some experimental clinical studies to measure soft tissue and volumetric changes allowing the assessment of outcome interventions. Nonetheless no guidelines are implemented to standardize the assessment methods[1]. Concerning periodontology, there are publications in the dental literature that use optical scanning-based digital technologies, for evaluating volumetric changes following implant placement, soft tissue augmentation at implant sites, ridge augmentation, ridge preservation and root coverage procedures[2–6].

Gingival recession is a condition that affects mostly adults when the root surfaces of one or more teeth are exposed due to an apical displacement of gingival tissues[7–10]. It can have several etiologies, which may be grouped into anatomical factors (e.g., lack of attached gingiva, muscular insertions near gingival margins, tooth misalignment, inadequate thickness of the alveolar bone plate, and root prominences), pathological conditions (e.g., periodontitis or viral infections), and iatrogenic factors (e.g., improper restorations within the biological space and mechanical trauma, including trauma associated with tooth brushing or lip piercing)[11].

Multiple studies have documented simultaneous treatment of contiguous recession defects using large, partial-thickness, coronally advanced envelop flaps, often including connective tissue grafts[12,13]. The tunnel approach with connective tissue grafts keeps papillary integrity and avoids vertical releasing incisions, allowing the treatment of multiple contiguous recession defects[14]. Similarly, buccal recession coverage with free autogenous soft-tissue grafts of epithelium and connective tissue has also provided consistent clinical results[14–16]. These grafts

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Patient ID	Age (years)	Gender	Tooth	Recession	CEJ	Step(+/−)	Surgical Approach
01	38	Male	16	RT1	Undetectable	+	Tunnel
			15	RT1	Detectable	+	
			14	RT1	Undetectable	+	
02	26	Female	23	RT1	Detectable	+	Tunnel
03	24	Female	13	RT1	Detectable	–	Tunnel
			14	RT1	Detectable	–	
			16	RT1	Detectable	–	
04	24	Male	34	RT1	Detectable	–	Tunnel
			35	RT1	Detectable	–	
05	23	Female	35	RT1	Undetectable	+	Tunnel
06	21	Female	31	RT1	Detectable	–	Tunnel
07	26	Female	14	RT1	Detectable	–	Tunnel
			24	RT1	Detectable	–	
08	29	Female	34	RT1	Undetectable	+	Tunnel
			35	RT1	Detectable	–	
			36	RT1	Undetectable	+	
09	20	Female	16	RT1	Detectable	–	Tunnel
			15	RT1	Detectable	–	
			14	RT1	Detectable	–	
10	24	Female	24	RT1	Detectable	–	Tunnel
			25	RT1	Detectable	–	

Table 1. Patients' and site-specific characteristics for the tunneling technique. *Recession* Cairo's recession classification, *CEJ* cementoenamel junction, *Class A* detectable CEJ, *Class B* undetectable CEJ, *Step* root surface concavity, + presence of a cervical step, – absence of a cervical step.

success has been attributed to the double-blood supply at the recipient site from the underlying connective tissue base and the overlying recipient flap[17,18].

However, the use of the intrasulcular approach to creating either a sub- or supraperiosteal space to extend beyond the mucogingival junction followed by the placement of a connective tissue graft is technically demanding[12] and has several disadvantages, such as the risk of perforation or trauma of the sulcular tissues[12], accidental papilla laceration, reduced coronal mobilization of the flap, reduced access for graft placement, and reduced papilla mobilization. The current techniques limitations also include scar formation at the recipient site resulting from surface incisions, yielding possible unfavorable healing outcomes[12,19]. On the other hand, it is assumed that avoiding visible incisions on the tissue surface allows for improved esthetics due to minimal soft-tissue trauma and post-operative scar tissue formation without complications during the healing phase[20,21]. Therefore, the vestibular incision subperiosteal tunnel access (VISTA) technique was developed to overcome some of the main drawbacks of other tunnel techniques reported in the literature[12].

There is still some lack of knowledge about the tissue thickness over the denuded root. Very few studies[22] have attempted to quantify soft-tissue thickness over the exposed root. Specifically, flap thickness has been shown to predict root coverage in mucogingival surgery[23,24], with 1.1 mm being the minimum thickness to achieve complete root coverage. However, there is still a lack of information about the assessment of periodontal biotype changes and volume gain after a connective tissue graft.

Therefore, this research aimed to develop and present a new digital evaluation protocol to objectively quantify the volumetric changes of root coverage periodontal plastic surgery, particularly the tunnel and VISTA techniques combined with connective tissue graft, with a 3- and 6-month follow-up. The null hypothesis established was: there is no difference on root coverage outcomes when applying two different periodontal plastic surgical techniques.

Results

Nineteen patients (4 males and 15 females) treated between December 2014 and January 2019 were enrolled in this study. Their mean age was 26.4 (± 7.9) years (age range, 17–48 years). One patient had recessions on anatomically separate locations of the maxilla, which derived in two independent surgical sites. A total of 38 recessions were treated for scientific evaluation. However, three patients from the Tunnel group did not attend the 6-month follow-up, and thus, only 32 defects were evaluated at 6 months, 15 tunnel and 17 VISTA. The TUN + CTG group contributed with 21 defects, and the VISTA + CTG group with 17 defects. Details regarding patients characteristics at baseline are shown in Tables 1 and 2. No complications occurred in any included patients during the follow-up period.

The superimposition was performed, and the results obtained showed mostly green surface which indicates both the study model and reference model corresponded to one another. Using the best fit algorithm, we obtained a more precise alignment minimizing the differences between the surfaces, this precision is translated by the Root mean square value (RMS) t shows how accurate the process is. A higher calculated RMS value indicated a

Patient ID	Age (years)	Gender	Tooth	Recession	CEJ	Step (+/–)	Surgical Approach
11	23	Male	21	RT2	Detectable	–	VISTA
12	21	Male	41	RT2	Detectable	–	VISTA
13	17	Female	41	RT1	Detectable	–	VISTA
14	28	Female	43	RT1	Detectable	–	VISTA
15	42	Female	16	RT1	Undetectable	+	VISTA
			15	RT1	Undetectable	+	
			14	RT1	Detectable	–	
16	22	Female	31	RT2	Detectable	–	VISTA
			32	RT2	Detectable	–	
			41	RT2	Detectable	–	
			42	RT2	Detectable	–	
17	22	Female	31	RT1	Detectable	–	VISTA
18	48	Female	24	RT2	Undetectable	+	VISTA
			25	RT1	Detectable	–	
19	23	Female	43	RT1	Detectable	–	VISTA
			44	RT1	Detectable	–	
			45	RT1	Detectable	–	

Table 2. Patients' and site-specific characteristics for the VISTA technique. *Recession* Cairo's recession classification, *CEJ* cementoenamel junction, *Class A* detectable CEJ, *Class B* undetectable CEJ, *Step* root surface concavity, + presence of a cervical step, – absence of a cervical step.

large error, i.e., the difference in the attributes between reference and measurement data. RMS mean value for the 0–3 months scans was 0.14 (±0.05) mm and 3 to 6 months was 0.12 (±0.03) mm as shown on Supplementary Table 2.

Gingival recession characteristics. Recession depth, recession area, and gingival margin thickness are described in Table 3. In the TUN + CTG group, ten experimental sites were RT1: a total of 21 recessions, including three cases of single-defect recessions and seven multiple-defect recessions. Mean baseline recession depth was 1.38 (±0.29) mm. The VISTA + CTG group included RT1 and RT2 recession types: a total of 17 recessions, including five cases of single-defect recessions and four multiple-defect recessions. Mean baseline recession depth was 1.60 (±1.02) mm. A statistically significant reduction of the recession area was observed at both 3 months and 6 months ($p < 0.001$ in both), independently of the technique used. No statistically significant changes were observed in the recession area between the 3- and 6-month follow-ups ($p = 0.613$) on tunnel (p-value = 0.317) and VISTA (p-value = 0.893) respectively. No statistically significant changes were observed in the mean gingival thickness and maximum gingival thickness in 2D or 3D (2DTHK, 2DTHKMax, 3DTHK, 3DTHKMax).

At the 3-month follow-up, root coverage was 95.6% (±14.5%) for the TUN + CTG Group and 88.9% (±20.5%) for the VISTA + CTG Group, with a recession reduction of 1.33 (±0.86) mm and 1.42 (±0.92) mm, respectively ($p = 0.337$). At the 6-month follow-up, root coverage was 96.5% (±10.4%) for the TUN + CTG Group and 93.9% (±10.3%) for the VISTA + CTG Group, with a mean recession reduction of 1.35 (±0.85) mm and 1.45 (±0.82) mm, respectively ($p = 0.455$). Complete root coverage was detected at 6 months in 86.7% (±0.4%) of the TUN + CTG Group and 70.6% (±0.5%) of the VISTA + CTG Group. No statistically significant differences were found between techniques (Table 4).

There was no significant thickness gain (2DTHK) between the 3-month and 6-month follow-ups ($p = 0.778$). Using the Mann–Whitney test to verify if the technique influences any variables, we found a statistically significant difference in the gingival margin thickness between the techniques ($p < 0.001$), confirming the surgeon's technique choice according to the gingival biotype, where the tunnel technique was chosen for thicker biotypes (Fig. 1A). Even though VISTA technique shows a higher maximum thickness gained at 6 months there are no statistically significant differences (3DTHK Max) ($p = 0.056$) (Fig. 1B).

The measured data indicate a certain soft-tissue thickness above which no further benefit was obtained in terms of surgical outcome. A logistic model was calculated with the complete root coverage as the target variable and the mean marginal soft-tissue thickness at 6 months as the covariable (3DTHK). This analysis indicated that a mean 3DTHK of 0.35 mm was necessary to predict a complete root coverage with 95% confidence.

Correlation between gingival margin thickness, papilla height, recession reduction area, and root coverage. A positive correlation was found between the gingival margin thickness and the recession reduction area at the 6-month follow-up ($r = -0.407$; $p = 0.025$). On the other hand, the gingival margin thickness was not correlated with Cairo's recession classification at 6 months ($p = 0.77$) or root coverage at both 3 months ($p = 0.560$) and 6 months ($p = 0.531$).

The papilla height was correlated with the recession reduction area at 6 months ($r = -0.636$; $p < 0.001$) and 3 months ($r = -0.626$; $p < 0.001$). However, the papilla height was not correlated with Cairo's recession

	TUNNEL + CTG		VISTA + CTG		
	Recession depth				
	n	**Mean ± SD (mm)**	**n**	**Mean ± SD (mm)**	***p*-value**
Baseline	21	1.38 ± 0.29	17	1.60 ± 1.02	0.601
0–3 months	21	0.05 ± 0.16	17	0.17 ± 0.29	0.322
3–6 months	15	0.04 ± 0.11	17	0.14 ± 0.30	0.433
	Recession area				
	n	**Mean ± SD (mm^2)**	**n**	**Mean ± SD (mm^2)**	***p*-value**
Baseline	21	4.23 ± 0.83	17	5.12 ± 6.07	0.561
0–3 months	21	0.25 ± 0.81	17	0.86 ± 2.11	0.352
3–6 months	15	0.25 ± 0.75	17	1.10 ± 3.15	0.433
	Gingival margin thickness				
	n	**Mean ± SD (mm)**	**n**	**Mean ± SD (mm)**	***p*-value**
Baseline	21	0.78 ± 0.34	17	0.50 ± 0.24	**0.000**
	2D mean gingival thickness (2DTHK)				***p*-value**
0–3 months	21	0.53 ± 0.28	17	0.54 ± 0.32	0.916
3–6 months	15	0.00 ± 0.18	17	0.01 ± 0.13	0.870
	2D maximum gingival thickness (2DTHK Max)				
	n	**Mean ± SD (mm)**	**n**	**Mean ± SD (mm)**	***p*-value**
0–3 months	21	1.20 ± 0.39	17	1.18 ± 0.48	0.902
3–6 months	15	0.43 ± 0.43	17	0.43 ± 0.26	0.982
	3D mean thickness of tissue over denuded root (3DTHK)				
	n	**Mean ± SD (mm)**	**n**	**Mean ± SD (mm)**	***p*-value**
3 months	21	0.34 ± 0.13	17	0.32 ± 0.16	0.693
6 months	15	0.34 ± 0.14	17	0.33 ± 0.16	0. 813
	3D maximum thickness of tissue over denuded root (3DTHK Max)				
	n	**Mean ± SD (mm)**	**n**	**Mean ± SD (mm)**	***p*-value**
3 months	21	1.19 ± 0.36	17	1.20 ± 0.46	0.968
6 months	15	1.10 ± 0.34	17	1.29 ± 0.47	0. 195

Table 3. Recession depth and marginal soft-tissue thickness (2DTHK, 2DTHK Max, 3DTHK, 3DTHK Max mm) at baseline, 3 months, and 6 months.

	Baseline: 3 months			Baseline: 6 months		
	Tunnel	**VISTA**	***p*-value**	**Tunnel**	**VISTA**	***p*-value**
Recession depth Reduction (mm)	1.33 ± 0.86	1.42 ± 0.92	0.931	1.35 ± 0.85	1.45 ± 0.82	0.706
% Root coverage	95.6 ± 14.5	88.9 ± 20.5	0.337	96.5 ± 10.4	93.9 ± 10.3	0.455
Area reduction (mm^2)	3.98 ± 2.49	4.26 ± 4.47	0.576	3.88 ± 2.29	4.02 ± 3.73	0.467
% Defects with complete root coverage	90.5 ± 0.3	70.5 ± 0.5	0.308	86.7 ± 0.4	70.6 ± 0.5	0.455

Table 4. Comparison of the Tunnel and VISTA Groups regarding recession depth reduction, percentage of root coverage, and percentage of defects with complete root coverage, at 3 and 6 months after surgery.

classification (p = 0.531) or the technique (p = 0.549). Also, no correlation was found between the papilla height and root coverage at both 3 months (p = 0.698) and 6 months (p = 0.315).

Healing dynamics of treated sites. The results of the volumetric assessments performed are shown in Supplementary Table 3. The soft tissue gained at 3 months was regarded as the standard value of soft-tissue augmentation, the grafted sites showed a mean gain at 3 months of 4.45 (± 3.42) mm^3 in the TUN + CTG Group and 5.27 (± 5.79) mm^3 in the VISTA + CTG Group (p = 0.772). At 6 months, the treated sites showed a mean gain of 4.72 (± 3.88) mm^3 in the TUN + CTG Group and 5.43 (± 5.21) mm^3 in the VISTA + CTG Group (p = 1.000). From T1 to T2 (6 months), there was a mean volume increase of 13.2% (± 5%), where the TUN + CTG Group showed a higher mean volume increase of 18.9% ± 58.4%) and the VISTA + CTG Group of 8.1% (± 53.1%) (p = 0.710).

The clinical outcomes can be observed in Fig. 2A and B.

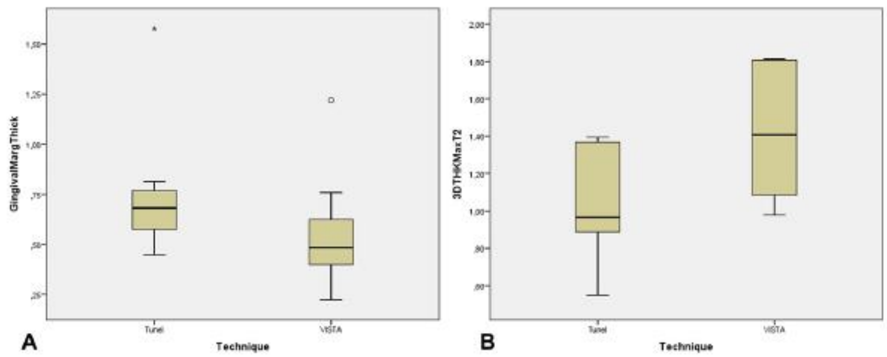

Figure 1. (**A**) Box-plot showing the gingival margin thickness (mean and interquartile range) of patients treated with the tunnel vs. VISTA techniques. Symbols (star and circle) indicate outliers of the study sample. (**B**) Box-plot showing 3DTHKMax T2 (mean and interquartile range) for patients treated with the tunnel vs. VISTA techniques.

Figure 2. (**A**) Baseline, (**B**) 6 months results.

Discussion

The digital evaluation protocol presented in this research is innovative as it adapts commonly measurements tools of a computer-aided-design software available mainly for engineering issues for a periodontology research in a way that was not found in the published literature, particularly in the analysis of variables like gingival margin thickness. In this research, a highly precise measurement method was used to evaluate the clinical outcomes of two different periodontal plastic surgical techniques in the treatment of gingival recessions. Within the limitations of this research, particularly related to the reduced sample size, the null hypothesis was not rejected, since no statistically significant differences were found in the clinical outcomes.

This research was done following the normal clinical environment of the University Dental Clinic. There was a full control of techniques and materials available for the surgical procedure to achieve the expected treatment success. The surgeon (T.M) had no knowledge that the presented research was being developed. Then, all the impressions were done by the author (N.S.) in a conventional way with alginate and cast models were obtained, as it were the commonly available dental materials. Although alginate has the lowest accuracy of all conventional impression materials, the use of regular casts that could include artifacts as those occurring in everyday practice offers a true representation of current clinical conditions[25]. Naturally, it could also account for part of the differences detected by different techniques, but it would do so in all cases, since the same methodology was used in every single case. It would be preferable to obtain the data directly with an IOS, to avoid a possible bias of conventional impression materials, but the availability of the IOS in the university dental clinic was not possible in all the moments, reason why the methodology described before was adopted.

The use of intraoral scanners goes back to 1987 known as the Chairside Economical Restoration of Esthetic Ceramics[26]. They were firstly used to measure alveolar ridge defects[6]. Since then, it has been successfully adopted to mucogingival surgery[22,27–29]. The intra-oral scanner used to do the 3D reconstruction of the cast models in the University Dental Clinic is from the year 2015. Although there are currently new IOS with better characteristics, this scanner allow to capture a precise image in small dimension areas as those that we have done[30,31]. It is not a IOS to perform a full-arch digitalization[32].

Considering the surgery techniques in evaluation, both showed recession reduction and complete root coverage. TUN + CTG and VISTA + CTG had similar root coverage results VISTA + CTG (95.6% (± 14.5%) and 88.9% (± 20.5%), respectively), with no statistically significant differences. Our study showed a mean root coverage superior to the latest systematic review and it can be explained by the microsurgical approach and the split-thickness used in the TUN + CTG[33]. Complete root coverage at 6 months was also highest in the TUN + CTG Group with 86.7% (± 0.4%) than the VISTA + CTG Group, with 70.6% (± 0.5%). However, both these differences might be due to all Cairo RT2 recessions being in the VISTA + CTG group, reducing the percentage of root coverage in this group. On the other hand, the higher recession reduction in the VISTA + CTG group of 1.42 (± 0.92) mm vs. 1.33 (± 0.86) mm in the TUN + CTG group is probably explained by the bigger recessions in the VISTA + CTG group[14].

The flap design is a key factor in the outcomes following root coverage and is considered a prognostic factor in the treatment of gingival recession defects[23,34,35]. Several studies have correlated greater flap thickness to better clinical outcomes after root coverage[36]. Also, a preoperative gingival marginal thickness greater than 1 mm correlates with a higher percentage of root coverage[28]. In our study, we described a unique non-invasive methodology to determine the pre-surgical gingival margin thickness. To the best of our knowledge a similar metrology technique was not found in previous published literature. The precise results obtained found a strong correlation with recession area reduction, which is in line with the literature. Gingival margin thickness can be used as a noninvasive surrogate for flap thickness measurement[37].

The correlation between marginal soft-tissue thickness and root coverage stability is still debated because not many researchers have actually aimed to assess the soft-tissue thickness over the exposed root surface[22]. It is believed that any increase in thickness will show long-term stability[22,38]. However, by comparing baseline and following soft-tissue profiles and volume differences, we can determine the thickness of the marginal soft tissues that have been obtained over the denuded root. Evidence has shown that combining the procedure with an autologous CTG is the most effective and predictable surgical approach for covering gingival recession defects[38–40].

The use of a de-epithelialized graft allows integration in the graft the connective tissue adjacent to the epithelium, which is denser, firmer, more stable, and supposedly more suitable for root coverage[41,42]. These types of CTGs demonstrate a greater increase of gingival thickness at the buccal aspect than subepithelial CTGs that lose a significant part of their thickness during the healing phase[41]. In our study, the amount of thickness gain needed for complete root coverage diverged considerably from the results by Zuhr et al.[27] because of the type of connective tissue harvested. We used a de-epithelialized graft, which tends to be more stable in terms of contraction than subepithelial grafts. The different measuring techniques could also explain such a difference.

In our study, the creeping attachment phenomenon happened due to increased volumetric alterations after 6 months, which disagrees with others papers published[22,27]. These dissimilarities are probably explained by the different types of connective tissue graft used in this study. Both cited papers[22,27] indicate a contraction of the graft, around two-thirds of the augmented volume was maintained after 12 months and soft-tissue healing was accomplished at 6 months. In our research, using a de-epithelized graft, we saw a mean volume increase after 6 months 13.2% (± 55%).

Our study's measured data indicated a certain soft-tissue thickness above which no further benefit was seen regarding the surgical outcome. Therefore, a logistic model was calculated with the complete root coverage as the target variable and the mean marginal soft-tissue thickness at 6 months as the covariable (3DTHK). This analysis indicated that a mean 3DTHK of 0.35 mm had to be maintained for predicting a complete root coverage with a confidence of 95%. This finding is confirmed by some recommendations on clinical decision making that incentivize the usage of thin CTGs for root coverage[38,43].

Volume changes and the healing process seems to be accomplished after 6 months[22]. We present new data indicating that grafted sites with de-epithelized grafts will experience a volume increase until the 6 months. However, due to this study's limitations, a higher patient number would be necessary to draw any valid conclusions. We now intend to conduct a 2-year follow-up to evaluate the stability of these types of grafts. We recommend small-sized and thin grafts because these could enhance the nutritional exchange between the recipient site, graft, and covering flap.

The present retrospective study has some limitations, including being retrospective, a small sample size, and having no randomization of treatments, direct digital impressions couldn't have been done in our study due to the availability of intra oral scans at the time the first patients were treated. Also, an esthetical evaluation could not be performed because of the retrospective characteristics of the analysis. This study is also limited in comparing the two techniques because thin biotypes and RT2 were treated with VISTA technique being the most suitable technique to avoid the risk of perforation or trauma of the sulcular tissues, papilla laceration, reduced coronal mobilization of the flap, and reduced papilla mobilization. The number of RT2 was higher in the VISTA group and could therefore influence the results. This study reports the 6-month outcomes of two techniques. The long-term stability regarding the increased gingival thickness is hypothetical.

Nonetheless, the used measuring method gives new insights in high-precision outcome evaluation after surgical recession treatment, ensuring the same region of interest is analyzed on all post-surgical time points, with an insignificant level of error and high reliability[5]. A new non-invasive method to measure the gingival marginal thickness was developed, and new outcome parameters that are not easily measured in the clinical setting were examined in this study. In future studies, a randomized control clinical trial should be done to compare both techniques digitally by analyzing the outcomes, using recently developed intra oral scanners, directly without conventional impressions. The technique currently taken as the gold standard is clearly invasive, too dependent on the individual operator, and calibrated in millimeters, unable to measure microns and gingival volume increase[5].

We characterized the healing dynamics of the grafted sites and assess the influence of the thickness in the newly created soft tissues on the outcome of the surgical techniques. This metrology technology allows for an unheard precision in linear measurements as in volumetric measurements and influences the study's outcomes. It cannot be compared with studies where the measurements are done using a periodontal probe, where a rounding error must be accepted.

The digital protocol here described can be applied in future research since it has several advantages: non-invasive, easiness, precise. One property of a new method of gingival volume assessment should be the discriminative capacity of distinct situation not only in pre-post assessment but also between comparable patients that were treated with distinct techniques. This non-invasive method has demonstrated to be able to capture significant pre-post difference and clinical relevant trends between both surgical techniques. Furthermore, it follows the evolution of digital technology in Dentistry, and results can be even more precise in a near future due to new IOS technologies being introduced by dental manufacturers. In summary, the applied metrology technology offers new insights in evaluating the outcomes after surgical recession treatment with the highest precision and accuracy with both techniques providing a reduction in gingival recessions and an increase in gingival thickness with no statistically significant differences. This promising method could be easily popularized mainly because there is no gold standard for non-invasive evaluations currently available.

Methods

All the surgeries were performed by the same surgeon (T.M.), without knowing that this research was being developed with the focus of achieving the best patient clinical outcomes. The clinical criteria of the surgeon to choose one technique over the other was related to the gingiva biotype and the root coverage procedure to be performed, according to the literature on this issue: thin biotypes were allocated to the VISTA technique and thick biotypes to the TUN technique[12]. Only in 2020, the authors decided to do this research, as a retrospective study, so there has been no bias of the surgeon clinical performance concerned to this research.

The study protocol was approved by the Ethics Commission for Health of the University (Comissão de Ética para Saúde da UCP, Report number 25, 4th of June 2020). Informed consent was obtained from all participants and all methods were performed in accordance with the Declaration of Helsinki principles for medical research involving human subjects and following the requirements established by Portuguese Law n.º 21/2014 for clinical research.

Participants.

All participants were selected among the patients that visited the Periodontology Area of the University's Dental Clinic. Consecutive patients with no loss of interproximal attachment (Cairo recession type 1 (RT1)) or loss of interproximal attachment equal or not greater than the buccal attachment (Cairo RT2) treated in the University's Clinic were enrolled in the study. Patients exhibiting single or multiple adjacent gingival recessions were treated, and all defects were included in the data collection. No single case was missed, overseen, or excluded. Interestingly, all Cairo RT2 recessions were included in the VISTA + CTG group.

Patients with one or more gingival recession defects who satisfied the following inclusion criteria were included:

- Periodontally and systemically healthy patients (for example, patients with ASA classifications I and II);
- Minimum of one Cairo RT1 or RT2 buccal or lingual gingival recession defect;
- Full-mouth plaque and bleeding scores $\leq$ 20%, no pocket depths > 3 mm, no active periodontal disease;
- Clinical indication and/or patient request for recession coverage;
- Radiographic evidence of sufficient interdental bone.

Teeth presenting root steps at the CEJ level and/or presence of root/crown abrasion and teeth presenting any sort of malpositioning were not excluded from the study. Exclusion criteria were the following:

- Cairo RT3 recession defects;
- Smokers;
- Teeth with cervical restorations
- Patients unable to undergo minor oral surgical procedures;
- Patients with a history of drug or alcohol abuse or psychiatric disorder;
- Pregnant patients;
- Uncontrolled periodontal disease or patient's unwillingness to undergo needed periodontal therapy around remaining teeth;
- Patients who had any systemic condition that could contraindicate any other surgical procedures.

Study. This research was designed as a retrospective cohort study. A post-hoc statistical analysis indicates that this study would require a sample size of 102 for each group (i.e. a total sample size of 204, assuming equal group sizes), to achieve a power of 80% and a level of significance of 5% (two sided). However, the periodontal plastic surgeries performed in the University Dental Clinic in the time-frame of this research were fewer, allowing to record data from 19 patients and 38 recessions (31 RT1 and seven RT2). With this reduced sample size, the post-hoc power was only 8%. Hence, this was considered a pilot research where a new digital evaluation protocol was used to objectively quantify the volumetric changes of root coverage periodontal plastic surgery techniques.

The clinical outcomes were digitally evaluated by a different researcher (N.M.S.), blinded to the treatment technique. This researcher did not know the case and the technique used. A number was assigned to each case, not having any kind of identification.

Using an intraoral scanner (Intraoral Scanner DentalWings; Straumann, Basel, Switzerland), at baseline, 3 months, and 6 months, the scans were performed by the same operator (N.M.S.), following the manufacturers scanning protocol limited to the quadrant or sextant affected by the gingival recessions.

Pre-surgical preparations.

Periodontal basic therapy was performed in all participants before surgery, included oral hygiene instructions and motivation, dental prophylaxis, and low-abrasive air polishing (Perio-Mate; NSK, Eschborn, Germany) as a mean of plaque removal[44]. Patients were required to use an atraumatic brushing technique with a soft toothbrush (Elgydium Clinic 7/100; Pierre Fabre Oral Care, Paris, France) or electrical toothbrush (OralB Smart 1500 Electric Rechargeable Toothbrush; Procter & Gamble, Cincinnati, Ohio, EUA) to eradicate harmful habits associated with the gingival recessions.

Surgical protocol. The tunnel approach was performed basically according to Zuhr et al.'s (2007) descriptions of a modified microsurgical tunnel technique[22,45,46].

Following an initial sulcular incision with a microsurgical blade (SB004/BW064; MJK, Marseille, France), tunneling knives and blades were used to create a split-thickness flap, to develop a continuous tunnel in the buccal or lingual soft tissues. The supra-periosteal dissection was extended well into the mucosal tissues for sufficient flap mobility. Papillae were carefully detached by a full-thickness preparation in their buccal aspect, thus allowing for a coronal displacement of the mobilized buccal soft-tissue complex[22].

The VISTA + CTG technique was performed according to Zadeh et al.'s descriptions of a modified microsurgical tunnel technique[12].

Following local anesthesia, root planning of the exposed root surface was performed with Gracey curettes (LM; LM-Instruments Oy, Parainen, Finland). Then, the residues were removed by copious irrigation with a sterile saline solution. The VISTA approach was performed with a mucosal buccal access incision mesial to the recession defects being treated. Mucosal and intrasulcular incisions around the involved tooth were performed using microsurgical blades and specially designed tunneling knives (Tunneling Kit; Deppeler, Role, Switzerland), creating a mucoperiosteal tunnel exposing the facial osseous plate and root dehiscence. This tunnel was extended at least one or two teeth beyond the ones requiring root coverage to mobilize gingival margins and facilitate coronal repositioning, employing the same tunneling knives. Additionally, the subperiosteal tunnel was extended interproximally under each papilla as far as the embrasure space allowed, without making any surface incisions through the papilla. Finally, to achieve complete mobilization of the flap, the interdental papillae were gently undermined using a specially designed tunneling knife (Tunneling instrument TKP; Deppeler, Role, Switzerland)[18].

The surgeon chose a de-epithelization approach of the posterior palate for CTG harvesting. The graft was thinned to a thickness of 1–1.5 mm and then slide into the previously created tunnel using a monofilament suture (Dafilon 6/0; BBraun, Melsungen, Germany).

Post-surgical protocol. The post-surgical protocol was adapted from Zuhr et al.[45]. The patients received 600 mg of ibuprofen (Spidifen 600; Zambon, Bresso, Italy) after the surgical procedure to reduce swelling and were instructed to avoid any mechanical trauma in the surgical site for 2 weeks.

Patients were instructed to rinse with Chlorhexidine digluconate 0.12% (Eluperio; Pierre Fabre Oral Care, Paris, France), three times per day for 2 weeks.

Two weeks after surgery, patients started to clean the teeth in the post-surgical area with a soft brush or electrical toothbrush. Every patient was recalled 3 months and 6 months post-surgery when clinical data were recorded, and accurate casts were obtained.

Digital measurements at baseline, 3 months, and 6 months. Accurate models were obtained at baseline and succeeding follow-up examinations, always under the same protocol: alginate impressions (Orthoprint; Zhermack, Badia Polesine, Italy) and gypsum study models (Vel-Mix white die stone; KERR, Bioggio, Switzerland), according to the manufacturer's instructions. This methodology was based on the publications of Gil et al.[28,29].

These models were optically scanned with (Intraoral Scanner DentalWings; Straumann, Basel, Switzerland), that has an accuracy of 20 µm (single unit), 50 µm (full arch) according to Dental Wings testing standard[47].

A new methodology that uses computerized measurement tools and design software was applied with (Geomagic Control X; Geomagic, Morrisville, EUA) and (Magics 23 Materialise; Materialise, Leuven, Belgium). This software were used to virtually superimpose each clinical case's pre-operatory 3D images subsequential follow-up scans and match them into one common coordinate system. All digital measurements were recorded to the nearest 0.01 mm as in Zuhr et al.[27]. The tooth surfaces were used as reference points for superimposing the different optically acquired files, allowing for accurate assessment of soft-tissue profile over the 6 months. A final alignment was done through the best-fit alignment algorithm[24].

(A further description of the digital protocol has been included in Supplementary Table 1 to share with clinician and researchers the major steps of this digital assessment.)

The following variables were analyzed fully digitally with the before mentioned software:

- Gingival margin thickness (baseline);
- Recession depth measured from CEJ to the gingival margin at the central buccal site;
- Area of the gingival recession;
- Height of the gingival margin papillae;
- Recession reduction;
- Area reduction;
- Complete root coverage;
- 2D mean gingival thickness gain at 3 months and 6 months (2DTHK);
- 2D maximum gingival thickness gain at 3 months and 6 months (2DTHK Max);
- Volume over the denuded root at 3 months and 6 months;
- 3D mean thickness of tissue over the denuded root at 3 months and 6 months (3DTHK);
- 3D maximum thickness of tissue over the denuded root at 3 months and 6 months (3DTHK Max).

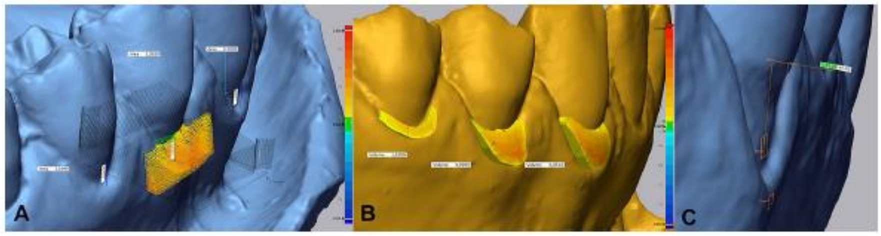

Figure 3. (**A**) Insertion of section plans perpendicular to ROI's entire length. (**B**) The volume of tissue over the denuded root obtained after connective tissue graft between T0 (baseline) and T2 (6 months). (**C**) Two planes are defined, and the distance between them is automatically calculated.

Two different methods to measure the soft-tissue thickness were applied using the protocol presented in Supplementary Table 1. The first method calculated the mean gingival thickness (2DTHK) and maximum gingival thickness (2DTHK Max) for each case at every time point, as seen in Fig. 3A. The second method involved a 3D assessment by limiting the recession in T0, T1, and T2 at the same time using transparencies to obtain the new volume of tissue over the denuded root for precise quantification of the tissue, as seen in Fig. 3B. In this case, the region of interest comprised the entire area of grafted soft tissue on the previously exposed root surface. Thus, the mean thickness of the marginal soft tissue (3DTHK) on the formerly exposed root surface, the mean gingival thickness (3DTHK), and maximum gingival thickness (3DTHKMax) were assessed for each case and each time point. Gingival margin thickness was measured using a new method that allows quantifying the margin thickness in a non-invasive way, as shown in Fig. 3C: two planes are defined, and the software calculates the distance between those two planes.

Statistical analysis. A dedicated computer software (Statistical Package for the Social Sciences, v24.0; IBM, Armonk, NY, USA) was utilized to carry out data analysis. Descriptive statistics were performed using mean values, standard deviations, frequencies, and percentages. Mean values were calculated from the parameters measured at the recession sites at different time points.

Differences were considered statistically significant at $p < 0.05$. Normal distributions were checked by Shaphiro-Wilk Test, however, given the small sample size of each group, the Mann–Whitney test (non-parametric) was used instead of the paired T tests. All hypothesis tests were conducted at the 5% level of significance.

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Author contributions

All authors have made substantial contributions to the conception and design of the study. T.M., N.M.S., have been involved in data collection and all surgeries were performed by T.M., data analysis was done by N.M.S., Statistical analysis was done by J.F. J.M., A.C., T.M. have been involved in data interpretation, drafting the manuscript, and revising it critically, all authors have given final approval of the version to be published.

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The authors declare no competing interests.

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CLINICAL IMPLANT DENTISTRY
and Related Research

ORIGINAL ARTICLE | Open Access

Effect of customized healing abutments on the peri-implant linear and volumetric tissue changes at maxillary immediate implant sites: A 1-year prospective randomized clinical trial

Danilo Fernandes DDS, MSc, Sílvia Nunes DDS, MSc, Gonzalo López-Castro DDS, MSc, PhD, Tiago Marques DDS, MSc, Javier Montero DDS, MSc, PhD, Tiago Borges DDS, MSc, PhD

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SECTIONS PDF TOOLS SHARE

Abstract

Background

Immediate implant placement (IIP) associated with the use of bone substitutes and collagen matrices (CM) seems to reduce the amount of resorption at peri-implant areas. Recently, customized healing abutments (CA) appeared as another solution in order to seal the socket and preserve the original soft tissue contour.

Purpose

To evaluate peri-implant tissues dimensional changes after using customized healing abutments compared with the use of xenogeneic collagen matrices as socket sealing options in flapless maxillary immediate implant placement.

Material and methods

The present study was designed as a prospective, randomized, controlled clinical trial. Patients were allocated into two groups depending on the socket sealing option: in the CM group a collagen matrix was used and in the CA group a customized abutment. Digital impressions were taken prior to extraction, 1, 4, and 12 months after implant insertion and the digital files allowed to evaluate linear buccal changes (MBC) and the buccal volumetric variation (BVv) between the different time points at peri-implant tissue areas. Additionally, mucosa variation was computed assessing the papilla presence and the midfacial mucosa height. Statistical significance was set at 0.05.

Results

Twenty-eight patients were observed during a 12-month period. Significant differences between mean values of BVv at the first month were observed at the CM and CA group (−9.75 ± 6.65% and −4.76 ± 5.29%, respectively) ($p = 0.043$). At the 1-year follow-up, no significant differences were found in terms of BVv between the two groups, although the thin bone phenotype (≤1 mm) significantly influenced the volumetric variations that occurred in each group. No significant differences were noticed in midfacial mucosa and papillae alteration between groups, after 1 year of treatment.

Conclusion

Both treatment options are predictable solutions for socket sealing in IIP, although a higher volumetric variation can be expected in the presence of thin bone phenotypes.

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Periodontology

ORIGINAL ARTICLE

Correlation between alveolar bone morphology and volumetric dimensional changes in immediate maxillary implant placement: A 1-year prospective cohort study

Tiago Borges, Danilo Fernandes, Bruno Almeida, Miguel Pereira, David Martins, Luís Azevedo, Tiago Marques,

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Abstract

Background

After a single tooth extraction, remodelling processes are initiated and morphological changes occur in the alveolar bone. It has been suggested that implant placement in a fresh extraction socket may partly reduce the alveolar ridge contraction and that several factors like the thickness of the buccal bone wall and the size of the gap between the implant and the facial bone wall may play a role on peri-implant tissues dimensional alterations.

Methods

Twenty-six patients treated with single-tooth maxillary implants were included in this study. A CBCT exam allowed to access the initial buccal bone thickness (BT). Digital impressions were taken prior to extractions (T0), 1 month (T1), 4 months (T2), and 12 months (T3) after implant insertion and superimposed with a computer software allowing to quantitatively analyse the three-dimensional changes occurred in the adjacent tissues. Variables related to thickness and volume were computed.

Results

Participants with BT ≤ 1 mm exhibited a significantly increased buccal peri-implant tissue thickness change than patients with BT > 1 mm (P = 0.049). At T3 patients representing BT ≤ 1 mm exhibited a total volume change of −8.53% ± 5.47% compared with patients presenting BT > 1 mm, −4.37% ± 2.08%. No statistical significance was found on the distance between implant shoulder and the buccal bone plate (BID) effect.

Conclusion

After the first year of treatment peri-implant tissues showed continuous changes resulting in a higher thickness and volume reduction at thin buccal bone plates.

CLINICAL ORAL IMPLANTS RESEARCH WILEY

ABSTRACTS | Free Access

Connective tissue grafts for root coverage: A 3D evaluation of the outcomes

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15809 Poster Display Clinical Research – Surgery

Background

In order to correct root exposures, different techniques have been recommended, among them, the vestibular incision subperiosteal tunnel access (VISTA) technique described by Zadeh and the modified tunnel technique proposed by Zuhr et al. The addition of a connective tissue graft (CTG) allows root coverage and gingival thickening and provides long-term stability to the gingival margin.

Aim/Hypothesis

To evaluate the mean gingival thickening, root coverage and volume gain at 3 and 6 months after the surgical procedure, comparing the results obtained between the two root coverage techniques with the use of a connective tissue graft.

Material and Methods

All consecutive patients with root exposure that needed a root coverage procedure were included in this cohort study. The gingival recessions were classified according to Cairo et al. criteria by a single experienced clinician. Three evaluation time points were defined - preoperative (T0), 3 months after the root coverage procedure (T1) and 6 months postoperatively (T2)Digital evaluation of the patients' casts was performed at T0, T1 and T2. The casts were digitalized with an intra-oral scanner (DentalWings®), obtaining an STL file. The software Geomagic Control X®, was employed to assess the three-dimensional changes of the soft tissues around the surgical procedure area. The following variables were evaluated- gingival recession area and dimension, mean thickness gain, maximum thickness gain, and volume gain. A descriptive and bivariate analysis of the data was made.

Results

A total of 39 gingival recessions (18 patients) were treated with either a modified tunnel technique with a CTG (22 type I recessions) or with a vestibular incision subperiosteal tunnel access with CTG (17 type 1 and 2 recessions). Both techniques provided a mean thickness gain of 0.5 mm, reaching maximum values >1 mm. Between T1 and T2 postoperative periods, no significant changes were observed. The mean root coverage for VISTA technique is 88.90% and for the Tunnel technique is 95.57%. No complications were described for the patients treated.

Conclusion and Clinical Implications

Digital tridimensional evaluation seems to be a useful tool to objectively assess the outcome of root coverage procedures, being feasible and accurate. Both techniques improved the thickness and volume of the soft tissue, allowing a good clinical root coverage with good aesthetic results and with low postoperative morbidity.

CLINICAL ADVANCES IN
Periodontics

CASE REPORT

Lingual Incision Subperiosteal Tunnel Access: Proof of Concept 18-Month Follow-Up

Joana Paiva Alves, Tiago Miguel Marques, Nuno Bernardo Malta Santos, Manuel Correia Sousa, Célia Coutinho Alves, André Ricardo Correia,

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Abstract

Introduction

Gingival recession is a common manifestation in most populations. The mechanism by which gingival recession occurs is not well understood but it seems to be complex and multifactorial. The main etiological factors are the accumulation of dental plaque biofilm with the resulting inflammatory periodontal diseases and mechanical trauma due to faulty oral hygiene technique, especially in thin biotypes.

Case Presentation

This case report describes the treatment of lingual recessions associated with bone loss, with a lingual incision subperiosteal tunnel access (LISTA) technique associated with a connective tissue graft. Nine months after the surgery, clinically significant root coverage and increased thickness of keratinized tissue were achieved; the patient was observed at 9, 12, and 18 months.

Conclusion

The clinical results, although without 100% root coverage, satisfied the patient entirely. LISTA technique associated with a connective tissue graft is a promising alternative for minimally invasive treatment of multiple lingual gingival recessions.

CLINICAL ORAL IMPLANTS RESEARCH WILEY

ABSTRACTS | Free Access

Correlation between alveolar bone features and dimensional changes at immediate implant sites

Danilo Fernandes, Tiago Marques, Miguel Pereira, Bruno Leitão, Andrè Correia, Tiago Borges,

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16097 Poster Display Clinical Research – Surgery

Background

After a single-tooth extraction, remodelling processes are initiated and morphological changes occur in the alveolar bone. It has been suggested that implant placement in a fresh extraction socket may partly reduce the alveolar ridge contraction and that several factors like the thickness of the buccal bone wall and the size of the gap between the implant and the facial bone wall may play a role on peri-implant tissues dimensional alterations.

Aim/Hypothesis

To evaluate the correlation between initial alveolar bone features and the peri-implant tissues volumetric changes following flapless immediate implant placement in the aesthetic zone, in the first year of treatment.

Material and Methods

Eighteen patients, treated with single-tooth maxillary implants after atraumatic flapless tooth extraction, between 15 and 25, were included. A previous CBCT exam confirmed the integrity of the buccal bone plate and allowed to digitally assess the buccal bone plate thickness (BT). The buccal plate-implant distance (BID) was measured between the implant surface and the inner buccal plate, previous to the xenograft bone substitute placement, to fill the gap. Digital impressions were taken prior to extractions (T0), 1 month (T1), 4 months (T2) and 1 year (T3) after implant insertion. The STL files obtained were superimposed with computer software to quantitatively evaluate the peri-implant tissues alterations. Mean buccal change (MBC), representing the variation on the facial side between T0 and postoperative follow-ups was computed. Mean values of MBC and the initial bone parameters were compared using a correlation coefficient and statistical significance was set at 0.05.

Results

Eighteen patients (mean age 52.76 ± 11 years), were evaluated after a 12-month period. A mean overall reduction in MBC was assessed in T0–T1 of −0.32 ± 0.26 mm, −0.35 ± 0.36 mm in T0–T2 and −0.38 ± 0.32 mm in T0–T3. Statistical analysis showed no significant correlation between BT classes (≤1 and >1 mm) and MBC values at T1 ($P = 0.064$) or at T3 ($P = 0.384$). It was observed that when BT > 1 mm, a mean increase of 0.51 mm in MBC T0–T1, 0.48 mm in MBC T0–T2 and 0.29 mm in MBC T0–T3 was noticed, showing a reduced volume loss at these sites. Also, when BID > 2 mm, it was observed a mean increase of 0.05 mm in MBC T0–T1, 0.13 mm in MBC T0–T2 and 0.40 mm in MBC T0–T3, although no significant differences were found between the two BID group sites (BID ≤ 2 and >2 mm) and the MBC changes.

Conclusion and Clinical Implications

Statistical analysis did not prove an influence of buccal bone plate thickness and the size of the gap values on thickness variation at the buccal side of the peri-implant tissues, even though a small sample size must be considered. Less tissue volume loss seems to occur when BT > 1 mm and BID > 2 mm, although no statistical significance could be found. Clinicians might take in consideration these two parameters in order to achieve functional and aesthetical improved results.

CLINICAL ORAL IMPLANTS RESEARCH WILEY

ABSTRACTS | Free Access

Multi-level volumetric changes at immediate implant sites – A retrospective case-control study

Danilo Fernandes, Tiago Marques, Miguel Pereira, Bruno Leitão, Andrè Correia, Tiago Borges,

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16204 Poster Display Clinical Research – Surgery

Background

After a single-tooth extraction, remodelling processes are initiated and morphological changes occur in the alveolar bone. Immediate implant placement associated with the use of bone substitutes and connective tissue grafts seems to reduce the amount of resorption at peri-implant areas. Despite the advantages with the use of these techniques, it is difficult to predict with precision what is going to happen after immediate implant placement, since it involves hard and soft tissue volume changes.

Aim/Hypothesis

To evaluate the volumetric changes in hard and soft peri-implant tissues after flapless immediate implant placement in the aesthetic zone during the first year of treatment.

Material and Methods

Eleven patients treated with single-tooth maxillary implants (Osseospeed EV, AstraTech Implant System, Dentsply Implants) after a traumatic flapless tooth extraction, between 15 to 25, were included in this study. A previous CBCT exam confirmed the integrity of the buccal bone plate. The horizontal implant bone gap was filled with a xenograft bone substitute. Digital impressions were taken prior to extractions (T0), 1 month (T1), 4 months (T2) and 12 months (T3) after implant insertion. The obtained STL files were superimposed with computer software allowing to create a colour map that quantitatively analysed the three-dimensional variations occurred in the intervened areas and adjacent tissues. Variables such as the Buccal Volume (BV) and Total Volume (TV) representing the volume changes between T0 and the different postoperative follow-ups were computed. Mean values were compared using a non-parametric test and statistical significance was set at 0.05.

Results

Eleven patients (mean age 52.54 + - 11.92 years), were evaluated after a 12-month period. No complications occurred in all included patients and implant sites during the follow-up period. Statistical analysis could not found significant differences between mean values during the three different postoperative time periods ($P = 0.717$). During the first month of treatment (T0–T1) it was observed a volumetric variation of −34.41 mm^3 on the buccal side and a total variation of −62.39 mm^3. Between the first and the fourth month (T1–T2) a volumetric alteration of −4.05 mm^3 on the facial aspect and a total alteration of −4.85 mm^3 occurred. Finally, during the fourth month and the final postoperative follow-up (T2–T3) it was found a buccal volumetric variation of −4.10 mm^3 and a total variation of −6.01 mm^3.

Conclusion and Clinical Implications

Immediate implant insertion is a predictable treatment when a replacement of a missing tooth is required, although failed to prevent volumetric tissue loss on peri-implant areas. Whereas in the first month buccal and palatal alterations are similar, during T1–T2 and T2–T3 the most variations took place on the buccal side. The highest volumetric loss occurred during T0–T1, in contradiction with recent literature suggesting that the most variations occur during the first 4 months.

CLINICAL ORAL IMPLANTS RESEARCH WILEY

ABSTRACTS | Free Access

Palatal soft-tissue changes after connective tissue graft harvesting – Tridimensional evaluation

Sara Ramos, Tiago Marques, Santos Nuno, Tiago Borges, Andrè Correia, Manuel Sousa, Gustavo Fernandes,

First published: 25 September 2019 | https://doi.org/10.1111/clr.494_13509

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15849 Poster Display Clinical Research – Surgery

Background

Sub-epithelial connective tissue grafts are considered a gold standard regarding root coverage procedures. Several authors have different opinions about the surgical technique. Some suggest a single incision technique, promoting primary intention healing at the donor site, inducing less postoperative morbidity to the patient. Others propose the de-epithelialized tissue graft, having a better view of the surgical site and advantages in gingival thickness.

Aim/Hypothesis

To compare the healing pattern in the lateral palate following harvesting of connective tissue graft at 3 and 6 months postoperative by two different harvesting techniques.

Material and Methods

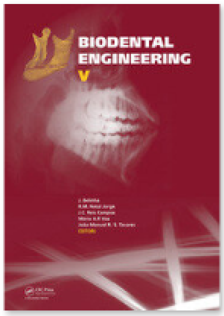
This is a prospective cohort study, over a period of 6 months. Three evaluation times were defined - surgery day (T0), 3 months (T1) and 6 months postoperative (T2). Patient's casts were performed at T0, T1 and T2. The casts were digitalized by an intra-oral scanner (DentalWings®), obtaining an STL file for each situation. In the computer program, Geomagic Control X®, the three-dimensional digital analysis of the intervened areas was recorded, defining as the interest area the distance between the distal border of the canine till the mesial half of the first molar. The following variables were analyzed- mean thickness loss, maximum thickness loss, mean maximum thickness loss and volume alterations. A descriptive and bivariate analysis of the data was made.

Results

A total of 19 lateral palatal donor sites were used to harvest a connective tissue graft with either sub-epithelial technique by Hürzeler MB. & Weng D. (4 clinical cases) or with de-epithelized tissue graft technique by Zucchelli, G. et al. (14 clinical cases). Comparing both groups, major volume and thickness loss was associated with the single incision technique, whereas the de-epithelialized technique as shown to have fully recovered in some cases at 3 months postoperative. In two of the cases was noticed volume gain, each from a different technique. The one included in group 1 as suffered postoperative necrosis, healing by primary intention.

Conclusion and Clinical Implications

The de-epithelialized technique as shown to implicate less tridimensional changes at the palatal donor site in comparison with the single incision technique, being less invasive and a better surgical option in cases requiring multiple tissue graft harvesting. Nevertheless, both found to be effective in root coverage procedure outcomes.



Chapter

3D analysis of the clinical results of VISTA technique combined with connective tissue graft

By D.S. Martins, L. Azevedo, N. Santos, T. Marques, C. Alves, A. Correia

Book Biodental Engineering V

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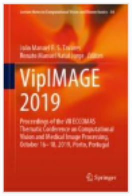
ABSTRACT

AIM: To evaluate with precision the percentage of root coverage and the increase of soft tissue volume, in single gingival recessions, treated by VISTA+CTG technique. MATERIAL METHODS: Three patients with Miller Class III single gingival recessions in incisors (maxillary or mandibular) were treated by VISTA+CTG technique. Patient's casts were recorded at baseline (T0), 3 and 6 months after surgery (T1 and T2, respectively). The cast were digitalized by an intra-oral scanner and they were superimposed in Geomagic Control X® to evaluate and quantify the changes occurred in 3D. RESULTS: At 6 months, VISTA+CTG technique ensure a gingival recession reduction as well as mean root coverage (2,49 mm and 81,28% respectively) and a gingival thickness increase (average 1,17± 0,36 mm). CONCLUSIONS: The results shows that the technique utilized was predictable for the treatment of this gingival recessions and may promote with success the root coverage and the gingival thickening, within the follow-up time frame.



ECCOMAS Thematic Conference on Computational Vision and Medical Image Processing
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Intraoral Scan and 3D Analysis of Periodontal Plastic Surgery Outcomes

Authors | Authors and affiliations

Sara Ramos, Tiago Marques, N. M. Santos, M. Sousa, G. Fernandes, A. Correia

Conference paper
First Online: 28 September 2019

Part of the Lecture Notes in Computational Vision and Biomechanics book series (LNCVB, volume 34)

Abstract

Intraoral scanning it's an emergent asset in Dentistry. 3D image capture has its guaranteed place in the future, replacing old traditional impression methods, consuming less time regarding to the planning process with exceptional precision. In this study, we present one of the many advantages that come with the use of this devices and their complement with digital programs, giving us a tridimensional full analysis on periodontal plastic surgery procedure outcomes, helping surgeons to understand the healing dynamics process.

CLINICAL ORAL IMPLANTS RESEARCH WILEY

ABSTRACTS | Free Access

Multi-level early volumetric changes at immediate implant sites – a retrospective case-control study

Tiago Borges, David Simões Martins, Luís Azevedo, Tiago Marques, Bruno Leitão Almeida, Miguel Pereira,

First published: 08 October 2018 | https://doi.org/10.1111/clr.351_13358

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12637 E-POSTER CLINICAL RESEARCH – SURGERY

Background

The reduced healing time and successful survival rates of immediate placed implants have been greatly documented in several studies with comparable results to the original protocol. The geometry of the implant and grafting procedures witch fill the facial gap likely reduce the buccal bone resorption that presents as a major risk for the achievement of an improved esthetic result, knowing that the midpoint of the fresh socket will resorb the double than the mesial and distal points.

Aim/Hypothesis

To investigate the early healing events, focusing on the volumetric changes of soft tissues and the alveolar bone walls of fresh extraction sockets following immediate implant installation.

Material and Methods

Eight patients treated with single-tooth maxillary implants (Osseospeed EV, AstraTech Implant System, Dentsply Implants) after atraumatic flapless tooth extraction were enrolled in this study. A previous CBCT exam confirmed the integrity of the buccal bone plate and implants were placed in a palatal position. The horizontal implant buccal bone gap was filled with a xenograft bone substitute. Digital Impressions were taken prior to extraction (baseline), 1 (T1) and 4-months (T2) post-implant placement, and superimposed with software for quantitative evaluation of the peri-implant tissue contours. Variables such as the buccal volume variation (BV), the buccal-palatal section variation (BPS) and the buccal area, were computed. Clinical measurements were taken as follows – probing depths, bleeding on probing, buccal height of keratinized mucosa and buccal plate-implant distance (BID). Mean values were compared using a correlation coefficient and statistical significance was set at 0.05.

Results

Eight patients, mean age 49.58 ± 11.09 years, were evaluated after a 4-month period. No complications occurred in all included patients and implant sites during the follow-up period. A mean KM height of 4.66 ± 1.5 mm (range 2–6 mm) and a mean BID of 3 ± 1.09 mm (range 2–5 mm) were assessed. A total volume reduction of −33.61 ± 32.35 mm^3 and −14.89 ± 10.39 mm^3 was noticed from baseline to 1-month evaluation and from baseline to 4-month evaluation, respectively. The linear measurements calculated based on the cross section image from baseline, showed a reduction of −0.22 ± 0.31 mm of the buccal position of the tissues at T1, and −0.03 ± 0.16 mm at T2. The relation between the buccal bone-implanted gap size (BID) and the buccal volume variation showed no significant correlation ($P = 0.718$), although a small sample size must be considered.

Conclusions and Clinical Implications

The immediate installation of implants in fresh sockets with the concomitant use of DBBM particles seems to be a predictable treatment option in the maxillary arch, although failed to prevent some of the tissue volume loss related to the teeth extraction. The size of the buccal bone-implant gap did not prove to influence the buccal tissue volume variation although the small sample size and study design must be taken into account when drawing clinical recommendations for clinicians.

Journal of Clinical Periodontology
EFP Official scientific Journal of the European Federation of Periodontology and its member National Societies

E-Poster | Research Presentation | Free Access

PR328: Palatal soft-tissue changes after connective tissue harvesting – preliminary results of a 3D volumetric analysis

First published: 20 June 2018 | https://doi.org/10.1111/jcpe.329_12915

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T.M. Marques, N.M. Santos, M. Sousa, C.C. Alves, A. Correia

Viseu/Portugal

Background & Aim: Subepithelial connective tissue grafts (SECTG) remain the most commonly used procedure for most root coverage procedures. Several authors have different opinions considering the surgical technique. Some suggest a single incision technique to harvest SECTG, with advantages of healing, with primary intention at the donor site and less postoperative morbidity to the patient. Others propose the de-epithelialization of free gingival grafts with advantages in gingival thickness showing no difference in discomfort or analgesic consumption when compared to single incision technique. The aim of this research was to compare the healing pattern in the palate following harvesting of connective tissue graft by these two different techniques.

Methods: Research sample was obtained from the Periodontology Service of a University Clinic. Following inclusion/exclusion criteria, seven patients were selected. They presented single or multiple tooth recession. Group I (n = 2) Patients were treated with single incision technique and Group 2 patients (n = 5) were treated with a de-epithelialized gingival graft. Pre-surgery cast models were done T0, T1 (3 months) and T2 (6 months). The cast models were scanned using an intra-oral scanner (Dentalwings®) and compared in software Geomagic Control X (®3D Systems) to evaluate the loss of palate volume. Due to sample size, only a qualitative analysis was done.

Results: Comparing both groups, a significant larger wound size was observed in Group I. In one case, after 3 years, loss of palatal volume was still noticeable. Group II showed a smaller wound size. In two of the patients the loss of volume was undetected after 3 months.

Conclusion: When evaluating de-epithelialized gingival grafts and the ones obtained using the single incision technique, the de-epithelialized technique was found to be better and less invasive than the single incision technique for harvesting the connective tissue graft, whereas both the techniques were found to be effective in root coverage procedure outcomes.

Title:	Avaliação tridimensional dos resultados clínicos do uso de enxerto de tecido conjuntivo nas técnicas vista e tunelização modificada para recobrimento radicular
Author:	Martins, David Miguel Simões e
Advisor:	Correia, André Ricardo Maia Alves, Célia Filipa Gonçalves Coutinho Marques, Tiago Miguel Santos
Keywords:	Recessão gengival Cirurgia plástica periodontal Enxerto de tecido conjuntivo subepitelial Recobrimento radicular Espessura gengival Gingival recession Periodontal plastic surgery Subepithelial connective tissue graft Root coverage Gingival thickness
Defense Date:	26-Jul-2018
Abstract:	Introdução: O tratamento de recessões gengivais (RG) unitárias, maxilares e mandibulares, pode ser feito com recurso a várias técnicas de cirurgia plástica periodontal (CPP), entre elas a técnica VISTA e a técnica de Tunelização modificada por Zuhr. A associação de um enxerto de tecido conjuntivo (ETC) a diferentes técnicas de CPP permite o recobrimento radicular e o aumento da espessura dos tecidos gengivais e confere estabilidade à margem gengival, a longo prazo. Objetivos: Avaliar, de forma prospetiva o ganho médio de espessura gengival e o recobrimento radicular, aos 3 e 6 meses de pós-operatório; o pós-operatório imediato, sentido pelos pacientes operados; bem como o resultado estético obtido, após 6 meses de cicatrização. Materiais e Métodos: Estudo prospetivo de coorte, num período de 6 meses. Três tempos de avaliação: dia da cirurgia (T0), 3 meses (T1) e 6 meses depois da cirurgia (T2). Amostra: 5 pacientes, com 6 RG unitárias, maxilares e mandibulares. Três RGs, classes I de Miller, foram tratadas com um ETC associado à técnica de Tunelização modificada por Zuhr, O. et al. (2007), enquanto que as 3 RGs, classes III de Miller, foram tratadas com um ETC associado à técnica VISTA, descrita por Zadeh, H. (2011). Protocolo da avaliação digital: efetuaram-se modelos de estudo a cada paciente operado, em T0, T1 e T2. Os mesmos foram digitalizados com um scanner intra-oral (DentalWings®), obtendo-se um ficheiro STL para cada situação. No programa informático, Geomagic Control X®, efetuou-se a análise digital tridimensional, das áreas intervencionadas. Resultados: As técnicas VISTA + ETC e Tunelização modificada + ETC, aos 6 meses de pós-operatório, permitiram, respetivamente: um ganho médio de espessura gengival de 1,35 mm e 0,81 mm; bem como uma % de recobrimento radicular de 81,28 % e 66,58 %. Conclusão: Dentro das limitações deste estudo, as duas técnicas de cirurgia plástica periodontal permitem obter: um espessamento gengival considerável; bem como um recobrimento radicular das RGs tratadas com sucesso clínico associado a um bom resultado estético.

Title:	Avaliação tridimensional do processo de cicatrização do palato lateral por comparação de duas técnicas de recolha de enxerto de tecido conjuntivo
Author:	Ramos, Sara Patrícia Figueiredo Fonte
Advisor:	Borges, Tiago Gonçalves Ferreira Marques, Tiago Miguel Santos
Keywords:	Cirurgia plástica periodontal Tecido conjuntivo Enxerto de tecido Dinâmica da cicatrização Avaliação volumétrica Periodontal plastic surgery Connective tissue Tissue graft Healing dynamics Volumetric analysis
Defense Date:	26-Jul-2019
Abstract:	Introdução: Os enxertos de tecido conjuntivo são frequentemente utilizados em procedimentos de recobrimento radicular. Sugere-se a técnica de incisão única, promovendo cicatrização por intenção primária no local dador, estando descrito que poderá induzir menor morbidade pós-operatória ao paciente. Outros propõem o enxerto gengival livre, conferindo melhor visualização do campo operatório e vantagens a nível de espessura gengival. Objetivo: Comparar o padrão de cicatrização do palato após a recolha de enxerto de tecido conjuntivo nos tempos pós-operatórios de 3 e 6 meses através de dois tipos de técnicas de recolha. Materiais e Métodos: Estudo prospetivo de coorte, num período de 6 meses composto por três tempos de avaliação: dia da cirurgia, 3 meses e 6 meses depois da cirurgia. A amostra compreendeu 19 locais de recolha do palato lateral: quatro enxertos subepiteliais (SE) removidos através da técnica "single incision" descrita por Hürzeler MB. & Weng D.; os restantes 15 enxertos desepitelizados (DE) foram removidos através da técnica descrita por Zucchelli, G. et al. O protocolo da avaliação realizou-se através de uma análise digital: efetuaram-se modelos de estudo a cada paciente operado, nos tempos prédefinidos, sendo os mesmos digitalizados com um scanner intraoral (DentalWings®). Nos programas informáticos, Geomagic Control X® e Materialise Magics®, efetuou-se a análise digital tridimensional das áreas intervencionadas. Resultados: Em relação à técnica SE calculou-se uma alteração média da espessura e volume de 0,36mm e 77,52mm3, respetivamente, em T1, e, de -0,10mm e 16,99mm3, respetivamente, em T2. No grupo DE calculou-se uma alteração média da espessura e volume de -0,26mm e 46,99mm3, respetivamente em T1, e, -0,25mm e 50,53mm3, respetivamente, em T2. Conclusões: A recolha de ETC promove alterações a nível dos tecidos moles do palato duro, podendo ocorrer ganho e/ou perda de volume/espessura; aparentam não estabilizar nos primeiros 3 meses, ocorrendo alterações subsequentes. Não existem diferenças significativas entre as técnicas em estudo. A avaliação digital tridimensional demonstrou possuir um carácter inovador, permitindo estudar a dinâmica da cicatrização de tecidos moles.

X ETHICAL

This study has an observational retrospective design and, therefore, few ethical considerations are raised.

This project was carried out applying the ethical principles of the Declaration of Helsinki and in accordance with the requirements established by Lei n. º 21/2014 for clinical investigation in the Portuguese Republic.

The personal data used in this study was safeguarded at all times. This data was protected in accordance with the provisions of the Data Protection Law duly implemented in the University Dental Clinic of the UCP, in Viseu. The data collected for the study was identified by a code and only the researcher was able to relate them. The personal data was treated with absolute confidentiality in accordance with the Data Protection Law and remained in the patient's clinical history.

The aim of the study was focused on a new informatics methodology to analyze biological outcomes of surgical techniques that are routinely described in detail in the literature.

UNIVERSIDADE CATÓLICA PORTUGUESA

Parecer sobre o projeto nº 25

Comissão de Ética para a Saúde da Universidade Católica Portuguesa

Mandato 2018/2021

Projeto de Investigação

Na reunião do dia 04 de junho de 2020 a CES-UCP esteve reunida e apreciou do ponto de vista ético os elementos submetidos pela investigadora, em resposta aos requisitos apresentados em parecer precedente. Sobre a apreciação redige o parecer que agora se apresenta.

Título: Volumetric changes of gingival recession after periodontal plastic surgery: a new method for the colletion and measurement of standardized and reproducible data

Investigador Principal: Tiago Miguel Santos Marques

Orientadores: Javier Montero (Universidade de Salamanca) e André Correia (UCP)

Resumo: O projeto em apreço engloba, na realidade, dois subprojectos:

- "Avaliação tridimensional dos resultados clínicos do uso de enxerto de tecido conjuntivo nas técnicas VISTA e Tunelização modificada para recobrimento radicular". Esta investigação tem como responsáveis: André Correia, Célia Alves, Tiago Marques e David Martins (estudante).

- "Avaliação tridimensional do processo de cicatrização do palato lateral por comparação com duas técnicas de recolha de tecido conjuntivo". Esta investigação tem como responsáveis: Tiago Borges, Tiago Marques, Nuno Malta e Sara Ramos (estudante). A recessão gengival é uma manifestação frequente em adultos, pensando-se que tenha por base um processo inflamatório. Na forma mais grave, pode expor toda a superfície de um ou mais dentes com descolamento apical dos tecidos gengivais.

A recessão gengival pode ser tratada através de várias técnicas cirúrgicas com processos de cicatrização variáveis, podendo originar cicatriz mais ou menos espessa, coloração variável, pequenas hemorragias, que poderão não corresponder ao efeito estético desejado elo paciente. Pretende-se monitorizar o efeito da técnica designada por VISTA e da técnica de "tunneling", ambas associadas a enxerto com tecido conjuntivo, de modo a avaliar as alterações volumétricas obtidas após a aplicação das técnicas de microcirurgia acima referidas (3 e 6 meses depois).

Os objetivos do estudo são:- Aplicação de metodologia inovadora, não referida ainda na literatura, para medição volumétrica do palato lateral, permitindo comparação dos resultados obtidos com as duas diferentes técnicas de reparação. O método usado será um scanner 3D intraoral – Dental Wings R (Straumann, Basel, Switzerland).- Comparação tridimensional dos tecidos moles após a aplicação da cobertura do túnel com enxerto de tecido conjuntivo subepitelial (TUN) e com enxerto de tecido conjuntivo (VISTA). É dito pelos investigadores que ambos os estudos não envolvem procedimentos cirúrgicos que não se enquadrem na prática clínica de rotina da especialidade. Tudo está conforme as exigências desta CES com algumas exceções que adiante se referem.

Estiveram presentes na reunião nº 18 da CES-UCP

Presidente: Doutora Mara de Sousa Freitas

Doutor Jerónimo Santos Trigo

Doutor Pedro Garcia Marques

Dr. Eugénio Fonseca

Doutora Ana Mineiro Zaky

Doutora Marta Brites

Mestre Ivone Gaspar

Conclusão

Ouvido o Relator, e o plenário da reunião do dia 04 de junho de 2020, realizada por vídeo conferência, esta CES delibera, por unanimidade, a emissão de **Parecer Favorável**.

Solicita-se ao Investigador Principal que, aquando da conclusão do estudo, lhe seja enviada uma síntese dos resultados obtidos e respetivas conclusões, via eletrónica, para o correio eletrónico da Comissão de Ética para a Saúde da Universidade Católica Portuguesa: ces.ucp@lisboa.ucp.pt

A Presidente,

Mara de Sousa Freitas

04/06/2020