



Interdental Papilla Regeneration: The Updates on Several Techniques

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Abstract

The procedure for regenerating interdental papilla is complex and technique-sensitive. However, the patient demand to reduce black triangle has dramatically increased in recent years. This article aimed to review the most recent surgical techniques on interdental papilla regeneration by reporting studies published from 2016 to 2021. A literature search was performed in electronic databases, including PubMed, Medline, and Web of Science using the following keywords: “interdental papilla regeneration,” “papillary reconstruction,” “surgical papillary regeneration,” and “hyaluronic acid injection.” Studies that have involved surgical techniques for interdental papilla regeneration as well as less invasive surgical procedure such as hyaluronic acid injections are comprehensively reviewed in this article. Techniques such as tunnelling and coronally advanced flap appear to have better success rate compared to other techniques. In view of graft, connective tissue graft resulted in successful interdental papilla regeneration with papillary fill maintained over long-term compared to concentrated growth factors. A less invasive option would be hyaluronic acid injection, but with less success rate compared to surgical procedures. However, the results were limited by the lack of standardised method to measure successful interdental papilla regeneration. This article comprehensively reviews the updates on interdental papilla regeneration techniques.

Keywords

- interdental papilla regeneration
- black triangle
- papillary reconstruction
- surgical papillary regeneration
- hyaluronic acid injection

Introduction

Black triangle (**► Fig. 1**) is the formation of triangular-shaped interdental space due to the interdental gingival recession. In the absence of interdental recession, this space is occupied by interdental bone and triangular shaped gingiva. The appearance of black triangle was not aesthetic and has been a matter of concern among patients.

Methods

This article aimed to comprehensively review the recent techniques used in surgical papilla regeneration. A literature search was performed in electronic databases, including PubMed, Medline and Web of Science using the following keywords: “interdental papilla regeneration,” “papillary reconstruction,” “surgical papillary regeneration,” and “hyaluronic

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Fig. 1 Black triangle.

acid injection.” The articles were screened to identify their relevance to this review.

Black Triangle Management

The intervention for black triangle has been performed for over six decades since 1956. The first report on conventional papilla preservation procedure was published by Kromer.¹ There has been a steady growth of evidence on the management of black triangle since then. Among the evidences reported, the semilunar incision proposed by Han and Takei has gained the most attention and preferred among researchers due to the predictability in regenerating interdental papilla by coronal displacement of the entire gingival papillary unit.² The restricted space in the interdental papilla requires pedicle graft instead of free graft to maintain sufficient blood supply.³

Thus far, proposed technique includes semilunar incision, roll technique, envelope and tunnel, and Beagle’s technique. However, in 2012, de Oliveira et al conveyed their concern on the predictability of the treatment approaches and preferred preventive therapy rather than surgical correction.⁴ In response to this statement, numerous surgical modifications using additional grafting materials have been carried out to further explore a more effective surgical technique.⁵ For the past 10 years, therapeutic focus has changed to a minimally invasive therapy. A recent article published in 2020 thoroughly reviewed the papillary regeneration procedures using hyaluronic acid (HA) injection and concluded that the application of HA may be effective to regenerate the lost interdental papilla.⁶

From 2016 to 2021, additional 18 studies concerning surgical interdental papilla regeneration has been published (► **Table 1**). One systematic review, seven randomised controlled clinical trials (RCT), four comparative studies, five case reports, and one narrative review were published. Recent evidence on the past 2 years based on RCT has resulted in a paradigm shift to using HA. There has been a shift in the trend of experimental study conducted, moving from invasive surgical procedures to minimally invasive surgical procedures. Therefore, this article aims to summarise the most recent scientific evidence and further appraise

Table 1 Publications concerning papilla regeneration techniques in 2016 to 2021

Type of studies	Number of publications
Systematic review	1
Randomised controlled clinical trial	7
Comparative study	4
Case report	5
Narrative review	1

the surgical techniques. The studies covered in this review are summarized in ► **Table 2**.

Throughout the years, there was an increasing number of studies reporting on successful cases with more cases reported in 2019 to 2021 compared to 2016 to 2018. Three cases^{15,16,23} reported on complete closure and the technique used was tunnel with connective tissue graft (CTG), envelope with concentrated growth factor (CGF), and semilunar incision with CGF. Six cases used HA in 2019 to 2021, while only one case used HA in 2016 to 2018. Generally, the use of surgical technique with CTG or CGF produced more cases with complete closure compared to HA.

Surgical Techniques

The semilunar incision technique² was still being used in the studies published between 2016 and 2021 with some modifications.^{13,16,17} The modifications include roll technique, tunnel, envelope, Beagle’s technique, and coronally advanced flap.

Semilunar incision is a technique performed to mobilise the gingiva-papillary unit coronally. The semilunar shaped incision was designed to avoid vertical incision and to preserve papillary integrity.^{13,16} The limitation for using this technique was the difficulty to insert graft if the vestibule was too shallow. Therefore, a case with shallow vestibule must be avoided and sufficient keratinised gingiva is needed when using this technique. Several studies used microsurgical and ophthalmic blades to elevate interdental papilla.¹⁶ The curved instrument was able to turn and elevate palatal papilla from buccal approach in an envelope type flap. The semilunar incision was relevant up to now with some modifications. However, careful patient selection and use of specialised instruments would yield a more predictable result.

In addition, tunnel technique with CTG was reported in several studies.^{22,23} This technique aimed to increase the papillary volume by filling the papilla with CTG following tunnelling. To coronally advanced the papilla, a suspensory suture was tied to incisally-placed composite. Similar to semilunar incision, specialised instrument was needed to elevate the interdental papilla from buccal to palatal.

The roll technique recreated the interdental papilla by rolling the buccal partial thickness flap.²² A trapezoidal

Table 2 Study designs and findings from studies concerning interdental papilla regeneration in 2016 till 2021

Systematic review		
Study	Aim	Findings
Ficho et al ⁶	To evaluate the stability of interdental papilla filling using HA	Four studies met inclusion criteria. ^{7–10} The weighted average percentage by sample size of papillary reconstruction after 6 months was 77.41% (SD: 20.68) with an average number of applications of 3.17 (SD: 0.31). The application of HA may be used to repair papillary defects. However, different experimental designs may contribute to contradictory findings
Randomised clinical trial		
Study	Technique	Findings
Abirami et al ¹¹	CTG as control, and platelet-rich fibrin as test	CTG and PRF groups showed reduction in black triangle compared to baseline; however, the black triangle was significantly less in CTG group compared to PRF after 6 months of study
Abdelraouf et al ¹²	HA injection compared to saline injection	Significant decrease in black spaces
Goyal et al ¹³	Semilunar incision with CTG (control) and PRF (test)	CTG resulted in better black space reduction and keratinised tissue width compared to PRF. Both showed improvement from baseline
Madel et al ¹⁴	Two different HA products compared to no HA group	Both HA type reduced black triangle immediately and 1 week after injection
Singh et al ¹⁵	CTG as control and PRF as test. A split thickness with envelope-type flap was elevated	Complete interdental space filling was observed in 90% of test group and 95% of control group after 3 months. Long-term study was suggested
Çankaya et al ¹⁶	Semilunar incision with CGF	Significant improvement over 1 year in papillary area compared to baseline in test group with positive correlation with papillary thickness and thrombocyte count
Turgut et al ¹⁷	Similar surgical procedure to Çankaya et al. ¹⁶ but reviewed after 2 years	All completely closed embrasures
Case reports		
Study	Technique	Findings
Chaulkar et al ¹⁸	Beagle's technique and modified Beagle's technique	Significant reduction in black space following modified Beagle's technique compared to Beagle's technique
Ni et al ¹⁹	0.05–1.0 mL of 16 mg/mL HA gel injection was administered three times with 3 weeks apart for each injection	Remarkable papillary restoration especially among thick biotypes
Alhabashneh et al ²⁰	Hyadent HA gel was injected using three steps technique	Significant black space reduction was observed and more reduction at maxilla compared to mandible Maximum reduction was observed after 3 months
Sharma et al ²¹	Coronally advanced flap with CTG	Significant reduction in vertical and horizontal component of black triangle with average of 60% reduction
Shenoy et al ²²	Case I: Partial thickness flap was rolled to create interdental papilla Case II: Combination of roll technique with composite restoration Case III: Envelope and tunnel flap with CTG	Almost complete black space closure for all cases. Roll technique with Cechi's modification is simpler and less painful for patient
Feuillet et al ²³	Tunneling with CTG	Complete closure in one case, and reduced black space in more severe case

Table 2 (Continued)

Systematic review		
Study	Aim	Findings
Kapoor and Dudeja ²⁴	Three injections of 0.2 mL 0.2% HA.	Significant improvement in all cases
Tanwar and Hungund ²⁵	Two injections of <0.2mL HA gel	Significant improvement assessed by photograph
Narrative review		
Study	Technique	Findings
Jamwal et al ⁵	<ul style="list-style-type: none"> • Semilunar incision • Papilla preservation • Palacci technique • Whale's technique • Beagle's technique 	Although there are many approaches have been proposed to restore interdental papillary loss, the predictability of the various procedures has not been completely documented

Abbreviations: CTG, connective tissue graft; HA, hyaluronic acid; PRF, platelet-rich fibrin; SD, standard deviation.

shaped incision was rolled in to create a voluminous papilla as a replacement to CTG. Subsequently, the donor site will heal by secondary intention and there was no second surgical site for CTG. This technique is successful in closing the black triangle and reducing surgical site compared to the semilunar technique; however, patient experienced more pain postoperatively.

On the contrary, Beagle's technique utilised pedicle graft from palatal aspect of papilla and the graft was mobilised to augment the black triangle. The incisions were made with an ophthalmic crescent knife, at the adjacent line angles of the interdental papilla, such that the length is more than the length of the black triangle space to be reconstructed.^{15,18,26} The difference between buccal and palatal graft was in the tissue texture and the results following surgery. Palatal tissue is harder in texture than the buccal tissue and difficult to manipulate. However, harvesting from palatal site will reduce aesthetic complication following surgery compared to harvesting from buccal site.

Connective Tissue Graft and Concentrated Growth Factors

Between 2019 and 2020, the experimental studies published have focused on the effectiveness of using platelet concentrates as a substitute to CTG. Four studies compared the efficiency of using platelet-rich fibrin (PRF) or CGF compared to CTG.^{7,13,15,16} CTG and CGF were successful in regenerating papilla with CTG showing superior results in terms of black triangle height reduction following 6 months.¹¹ There was a general agreement on the superiority of CTG compared to PRF or CGF in regenerating interdental papilla.^{7,13,18} The advantage of using CTG was the firmer texture and thus, better manipulation compared to CGF. The CTG was cut into T-shape to evenly increase the interdental papilla volume buccally and palatally.²³ With this shape, there was a better chance for papilla regeneration that could not be achieved when using CGF. In addition, the keratinised tissue width was significantly increased following use of CTG compared to CGF.¹³

In addition, the use of CGF in regenerating interdental papilla was shown to support the three-dimensional structure of interdental papilla up to 2 years.¹⁷ The disadvantage of using CGF includes difficult manipulation due to the soft texture. In addition, patients with blood problem incur limitation to this procedure. Turgut and coresearchers reported a relationship between platelet count and the success rate of the papilla regeneration following use of PRF.¹⁶ CGF is promising in the future with the advantage of overcoming second surgical site.

Hyaluronic Acid Injection

HA or Hyaluronan is a component in extracellular matrix that regulates the cells behaviour and tissue environment. It has been shown that HA regulates tissue regeneration and has been extensively used in aesthetic products. Recently, HA has been introduced as a less invasive procedure to treat black triangle. A systematic review including four studies published between 2010 and 2016 reported 77.4% (standard deviation: 20.68) papillary filling weighted by average sample size with an average of three times application.⁶ It was concluded that HA may be used to treat papillary defects; however, there was a still concern on the quality of evidence since different experimental designs were used.

From 2016 till now, six studies on HA have been published including two RCTs,^{12,14} two comparative studies,^{19,20} and two case reports.^{24,25} Black space reduction was noticed immediately after injection,¹⁰ significant improvement after 3 months,^{19,20} but less improvement was shown after 6 months.²⁰ There was a slight difference in the method of HA application. Two studies administered HA using three step technique whereby each step consisted of 0.1 mL HA injection at mucogingival junction, attached gingiva, and 2 to 3mm from tip of papilla.^{14,20} Alternatively, another study reported 0.1 mL HA injection at base of papilla and was repeated at 3 and 6 weeks.¹⁹ Generally, there was a significant papillary reconstruction with better results observed in Class I Nordland¹⁴ and thick gingiva.¹⁹ There was a promising



Fig. 2 Papillary housing (adapted from Gonzalez et al. 2011).

future for HA in regenerating defective papilla especially due to its less invasive nature.

Factors for a Successful Papilla Regeneration

In view of the difficulty to achieve complete black space closure, several factors have been identified to influence the success of a papillary regeneration procedure. The factors could be identified as anatomical factor, patient factor, type of graft, and case severity.

A complex papillary anatomy was discussed in detail in a review article²⁷ whereby the term papillary housing was being used. The shape of papilla is being depicted as a house using the term “papillary housing.”²⁸ The boundaries of this papillary housing were contact point as the roof of the house, proximal tooth surfaces as contour of roof, cemento-enamel junction courses as border between roof and walls, interdental distance as walls, and bone crest as the floors. The papillary house can be viewed via radiograph as shown in ►**Fig. 2**. Each of the papillary housing boundaries influences the regeneration of interdental papilla. Papillary housing in between central incisors is comprised of two mirror image proximal central incisors as the roof contour. The two steep roof contours conjoint to make a very high roof depicted as coronally placed contact point. In contrast to papilla between central and lateral incisors, different tooth contours may place the contact point more apically. It was reported that there was less black space closure in between central incisors compared to other teeth due to its symmetrical forms.¹⁶ Contact point placed more than 5 mm distance to bone crest has been associated with black space.²⁹ Additionally, periodontal disease that results in bone loss enlarges this papillary housing and largely contributes to black space and difficulty in papillary regeneration.

Square-shaped tooth is associated with thick gingiva whereas slender tooth is associated with thin gingiva.³⁰ Similarly, square-shaped teeth have a more apically positioned contact point that makes black triangle elimination more predictable. Furthermore, thick gingiva reduced the

surgical complications by preventing the gingiva from perforations. Thin gingiva needs delicate handling; therefore, careful manipulation is required. Thus, a higher success rate could be achieved among cases with thick gingiva compared to thin. Additionally, thick gingiva is commonly associated with wide keratinised tissue leading to a deep vestibule. Patients with deep vestibules are best candidates for semilunar incision technique particularly due to high possibility for surgical success.¹⁷

Patients with bleeding disorders are discouraged to undergo PRF and/or CGF procedures. Withdrawing blood in these patients not only causes internal and external bleeding but also compromises the quality of CGF and PRF. In wound healing, thrombocytes are responsible for blood clotting and help to stop bleeding. Furthermore, the PRF is composed of fibrin originated from platelets. Patients with low thrombocyte count may have a lower concentration of PRF thus compromising the quality of the PRF. The quality of PRF affected papillary regeneration performance by which lower papillary filling was shown among patients with lower thrombocyte count compared to patients with high thrombocyte count.¹⁶

Based on studies published between 2016 and 2021, there was a multitude of surgical modifications with the semilunar incision was still being used in the majority of cases as the principal technique.^{16,18,21–23} Among the surgical modifications performed are pedicle graft that leaves donor site heal by secondary intention termed as modified Beagle's technique,¹⁸ pedicle graft performed at buccal site,¹⁸ multiple papillary regeneration with single semilunar incision,¹⁶ and envelope type,^{15,23} split thickness flap,^{15,16} coronally advanced flap,²¹ and roll and tunnel technique.^{22,23} The Beagle's or modified Beagle's technique might leave a secondary intention site that will heal and give risk for thin gingiva, scarring, and compromised the aesthetics. The surgical modifications resulted in almost complete closure of the black triangle.^{15,16,22,23,31}

Based on the studies published between 2016 and 2021, there was a changing trend from using CTG as graft to more usage of PRF. PRF has shown a comparable performance to CTG in reducing black triangle with slightly inferior improvement in severe cases. CTG has specific biological tissue characteristics that substantiate CTG as a better matrix for augmentation.³¹ The inferior performance of PRF in some cases could be attributed to both case severity and lack of PRF quantification prior to the procedure.¹⁶ However, PRF can be obtained nonsurgically and may have deemed PRF a better option for patients compared to CTG.

In addition to surgical modifications, the use of new instruments facilitated manipulation of the delicate interdental papillary flap. Ophthalmic blade can prevent inadvertent severing of thin gingival tissues. The use of ophthalmic blade allows tunnelling and lifting of papillary unit without buccopalatal split,³¹ thus preserving vascularity for optimum regeneration. In contrast to when papillary regeneration was first introduced, microsurgical technique has been a compulsory armamentarium in performing papillary regeneration procedures nowadays. The papillary regeneration

was improved by the introduction of HA injection as a less invasive therapy.

Currently, no comparison was made between success rate of CTG and HA. However, HA was proven less painful compared to CTG. Following HA injections, papillary volume increased 3-month postinjections, but it was not sustained until 6-month. It was reported that there was a reduction in papillary volume 6 month after HA injection²⁰. This showed inferior long-term stability following HA injection compared to CTG. A longitudinal study is required to confirm the results. If HA is proven comparable, then why do we perform invasive therapy? A more patient-centered therapy with less pain and discomfort, less side effect, less expensive can be offered through HA injection. Further RCT need to be performed, and HA is a promising therapy for papillary regeneration.

Surgical technique using CAF principle eliminated black spaces by bringing the whole papillary unit coronally. In this case, there was lack of papillary regeneration because the papilla has been displaced to cover the black space. The reduction in black space was partially achieved by the reduction in buccal gingival recession due to the CAF technique. By this, it could mean that interdental papillary reconstruction can both treat black triangle and gingival recession especially in Miller class III.³² According to recession type (RT) classification, RT3 may not achieve full coverage. Using interdental papillary regeneration technique, RT3 has a brighter chance to be treated. A modern gingival recession classification by Cairo et al has classified recession based on the interproximal loss; recession type 1 (RT1), recession type 2 (RT2), and recession type 3 (RT3).³³ RT1 indicates gingival recession with no loss of interproximal attachment, and RT2 indicates gingival recession associated with loss of interproximal attachment. The amount of interproximal attachment loss is equal to or less than the buccal attachment loss. RT3 is gingival recession associated with interproximal attachment loss whereby the amount of interproximal attachment loss is greater than the buccal attachment loss. Based on this classification, it is difficult to achieve full coverage for RT3.^{33,34} Fortunately, there is a better chance to achieve full coverage for RT3 when interdental papillary regeneration is performed in addition to root coverage procedures. For the rest of this article, Miller classification will be used due to the majority of previous publications used Miller classification to classify gingival recession.

Majority of surgical reconstruction procedures were performed on Miller classes I and Miller II interdental recessions particularly due to the more predictable outcomes. Papillary regeneration in Miller class III was generally not predictable. It is easy to predict that Miller class I papillary recession has a higher success rate compared to Miller class II¹⁴ nonetheless, several techniques found no difference in papillary filling between Miller class I and Miller class II cases.²⁰ Other anatomical deformity could complicate the surgical procedure such as crowding, buccally placed tooth, and spacing. Aesthetically, aligning teeth must come first prior to correcting the papilla. By then, papillary defect due to spacing can be

corrected by orthodontic treatment. Thus far, there are many nonsurgical techniques in correcting missing papilla including contact point correction, orthodontic treatment, and preventive measures. The decision on choosing the right procedure is dependent on case selection and patient's preference.

Conclusions

Interdental papilla regeneration is a highly challenging treatment due to its restricted vascularity and reduced regenerative potential. A multitude of surgical modifications have been proposed to increase regenerative potential of the papilla. The author suggested surgical interdental papilla regeneration using CTG as graft and HA injection as a less invasive option. The choice of therapy should be based on patient's preference and careful case selection.

Clinical Significance

Interdental papilla regeneration is a valuable treatment to reduce black triangle. Recently, there was a growing evidence on the use of CGF and HA injection. Hence, there is a need to review the advantages, disadvantages, and treatment outcome of each technique to aid clinician for successful black triangle management.

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics Approval

This is a review article and no ethical approval is required. There was no human nor animals subject involved.

Consent to Participate

There was no involvement of human subject in this article, hence no consent was taken.

Consent to Publish

The authors affirm that human research participants provided informed consent for publication of the images in **Fig. 1**.

Authors' Contributions

HMY contributed to the idea for the article. NAAH performed literature search, data analysis, and first draft of the manuscript. NAAH and HMY commented and revised the final manuscript. All authors read and approved the final manuscript.

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Conflicts of Interest

None declared.

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