Universidad Europea

GRADUATION PROJECT

Dentistry Degree

RECOMMENDATION FOR ENAMEL STRIPPING IN THE ORTHODONTIC TREATMENT

Madrid, academic year 2022/2023

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ABSTRACT

Introduction: Enamel stripping is a common procedure part of the orthodontic treatment, where the interproximal enamel is stripped to create space in the arch in case of a mild to moderate crowding. **Objective:** The main objective was to determine which is the safest way to perform enamel stripping. To answer this, we compared manual and mechanical techniques, evaluated the usefulness of polishing, determined the need for remineralization and defined the safest margins on how much enamel can be removed. **Material and methods:** A literature review was performed through Medline Complete, ScienceDirect and Pubmed. **Results:** 51 articles were read from which 26 were selected. Between manual and mechanical techniques, the mechanical polishing discs left the smoothest enamel surface. Polishing proved to be essential to reduce the enamel roughness and Sof lex discs followed by 37% orthophosphoric acid showed the best results. The necessity of remineralization techniques are still under discussion but using a casein phosphopeptide-amorphous calcium phosphate varnish in the interproximal area is the most helpful tool to promote the enamel health after stripping. The width of the enamel is specific to each tooth and each individual but all authors agreed that 50% of the existing enamel is available for reduction. The use of X-rays is highly recommended to increase the success rate of the procedure. **Conclusion**: The safest way to perform enamel stripping is through the use of mechanical diamond discs followed by polishing with Sof-lex discs and the application of 37% orthophosphoric acid. The practitioner can remove up to 50% of the enamel. It is suggested to use a casein phosphopeptide-amorphous calcium phosphate varnish at the end of the procedure.

Key words: "Dentistry", "Interproximal enamel reduction", "Enamel stripping", "Air-rotor stripping", "Orthodontics".

RESUMEN

Introducción: El desgaste del esmalte es un procedimiento común en el tratamiento ortodóntico, donde se desgasta el esmalte interproximal para crear espacio en el arco en caso de apiñamiento leve a moderado. **Objetivo**: El objetivo principal fue determinar cuál es la forma más segura de realizar el desgaste del esmalte. Se compararon técnicas manuales y mecánicas, se evaluó la utilidad del pulido, se determinó la necesidad de remineralización y se definieron los márgenes más seguros sobre cuánto esmalte se puede quitar. **Material y métodos:** Se realizó una revisión bibliográfica a través de Medline Complete, ScienceDirect y Pubmed. **Resultados**: Se leyeron 51 artículos, de los cuales se seleccionaron 26. Entre las técnicas manuales y mecánicas, los discos de pulido mecánico dejaron la superficie de esmalte más lisa. El pulido demostró ser esencial para reducir la rugosidad del esmalte y los discos Sof-lex seguidos del ácido ortofosfórico al 37% mostraron los mejores resultados. La necesidad de técnicas de remineralización aún está en discusión, pero el uso de un barniz de fosfopéptido de caseína-fosfato de calcio amorfo en el área interproximal es la herramienta más útil. El ancho del esmalte es específico para cada diente y cada individuo, pero todos los autores coinciden en que el 50% del esmalte está disponible para la reducción. Se recomienda encarecidamente el uso de rayos X para aumentar la tasa de éxito del procedimiento. **Conclusión**: La forma más segura de realizar el desgaste del esmalte es mediante el uso de discos de diamante mecánicos, seguidos de pulido con discos Sof-lex y la aplicación de ácido ortofosfórico al 37%. El practicante puede eliminar hasta el 50% del esmalte. Se sugiere utilizar un barniz de fosfopéptido de caseína-fosfato de calcio amorfo al final del procedimiento.

Palabras clave: "Odontología", "Reducción de esmalte interproximal", "Desgaste de esmalte", "Desgaste con aire-rotor", "Ortodoncia".

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1. INTRODUCTION

1.1 Definition and current status of interproximal enamel reduction

The orthodontic treatments' main objective was defined by Charles H. Tweed, one of the founders of orthodontics, as a "healthy, esthetically pleasing, functional and stable occlusion, which should match an esthetically harmonious soft tissue profile " (1).

In order to achieve this balance, various methods and appliances have been developed throughout the years in order to gain or reduce the space present in the arch and to align the teeth. Enamel interproximal stripping also known as "interproximal enamel reduction (IER)", "air rotor stripping (ARS)", "reproximation" or "slenderizing" is a commonly used orthodontic procedure. It mainly consists in the abrasion of interproximal enamel surfaces to treat teeth crowding and improve the long-term maintenance of the treatment (2).

In other terms, slenderizing is based on the reduction of the enamel, its anatomic re-contour, to gain space in the treatment of mild to moderate crowding (4-8mm) " (3). It is considered a viable alternative to the extraction of permanent teeth, and helps to adjust the Bolton Index discrepancy" (3), as well as to simplify the long-term maintenance of the results (1).

The use of interproximal reduction can be found as a complementary intervention, in addition to an established orthodontic treatment, in order to reduce the dental crowding. It is used as an alternative to the usual procedures such as transverse arch expansion, anterior teeth proclination, distalization of the molars or extraction. The treatment will be determined based on the patient's age, facial profile and amount of crowding (1,3).

1.2 Historical background of enamel stripping

The first description of enamel stripping goes back to the 1940's with Ballard and Linn. Ballard in a quantitative study of 500 models, and Linn, were among the first to suggest the

reduction of mandibular anterior teeth proximal surfaces in order to harmonize discrepancy in tooth size (4).

Throughout the years, several authors developed their opinion on the use of IER. Hudson explained the combination of metallic strips, polishing and fluoride's use to perform IER. Peck and Peck advised the use of stripping to correct tooth shape deviation, noticing that the mesiodistal indices of lower teeth were significantly lower in well aligned incisors compared to crowded ones. Tuverson and Boese both pointed out in the same year that stripping could be considered, on top of orthodontic procedures, in order to enhance the results of the treatment. Sheridan in the 1980's brought light onto the use of this technique as an "alternative to extraction or expansion procedures in cases of mild to moderate crowding". Finally, Zachrisson described in 2004 the use of interproximal stripping to reduce the presence of black triangles, in adult patients, in order to improve the esthetic outcome of the orthodontic treatment (2,3,5).

1.3 Indications and contraindications of enamel stripping

1.3.1 Indications

To treat dental crowding, orthodontists can either increase the arch space or reduce the tooth mass. Stripping will be mainly used in cases of Bolton discrepancies, which refers to the difference in size between the mesiodistal diameter of the upper and lower teeth, when the discrepancy exceeds 1,5mm. When no arch space can be gained, in the case of very proclined lower incisors, and with no arch space available, stripping can be used to gain space and to avoid further proclination of the incisors, which would create the risk of root exposure (6).

1.3.1.1 Permanent dentition

IPR is mainly used in adults, in borderline cases, when patients present mild to moderate crowding in the dental arches. It is used to correct crowding ranging from 4 to 8mm, as an alternative to extraction or expansion (3). It is effective in the case of a mild midline deviation and in cases of increased overjet and overbite (6), when the patient presents a class I discrepancy (figure 1.) with an orthognathic profile or a minor class II dental malocclusion (figure 2.), (especially in non-growing patients) (1). Moreover, IER can be used in order to improve anterior aesthetics, prevent or reduce interdental gingival retraction (known as black triangles) (2), normalize the gingival contour and correct the curve of Spee. Stripping will also be used to enhance retention and stability post treatment (3), as well as to perform cosmetic recontouring to improve the teeth final shape (1).

1.3.1.2 Primary dentition

In deciduous teeth, stripping can be used in the conjunction of the Frankel I or II appliance (to correct a class I or class II division 1 malocclusion). It can be used when the 2nd premolar is missing and the primary molar has to be retained. Because the primary molar would have a bigger diameter than the permanent premolar, stripping can be used to reduce the mesiodistal diameter of the primary molar (7). It can also be used on temporary teeth to ease the eruption of the permanent teeth when they are blocked by lack of diastema space (8).

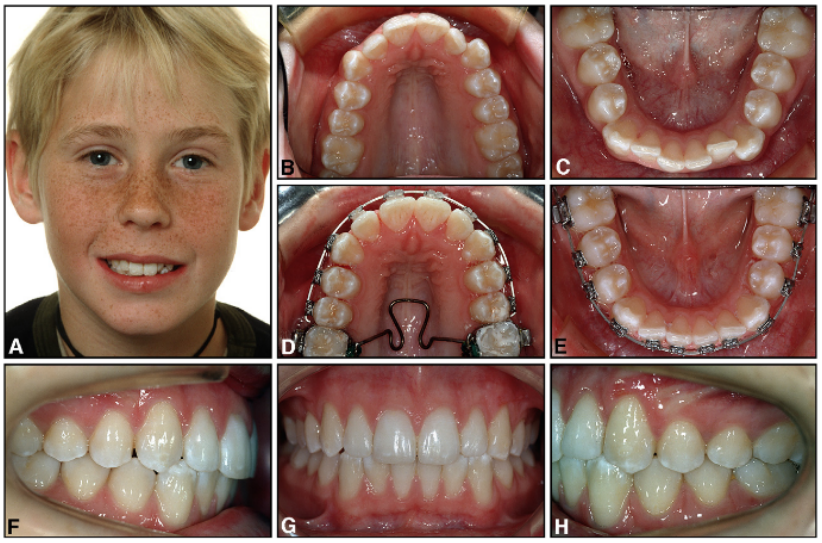

Figure 1. Case example of a 4 year follow up. Treatment of a Class I with bimaxillary crowding (boy of 13 years). Stripping performed in anterior and posterior regions. Improvement of first premolars morphology. (9)

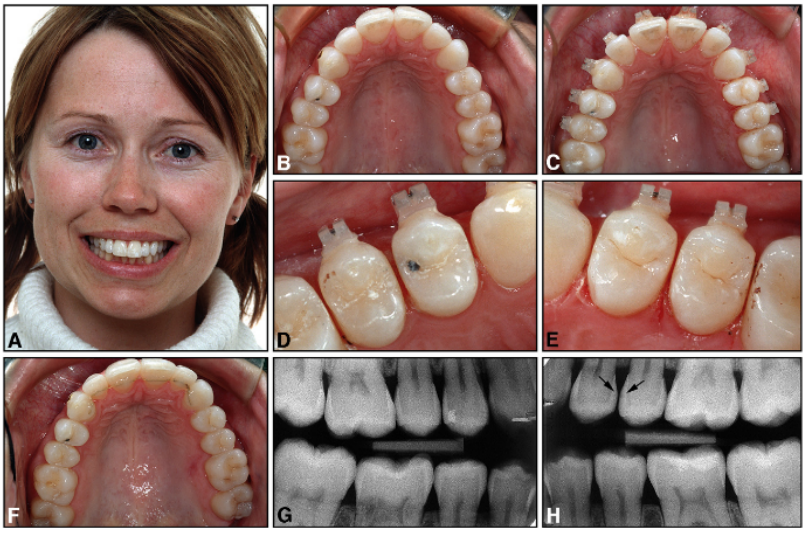

Figure 2. Case example of a 6 year follow up. Treatment of Class II with mandibular crowding. Stripping performed on all teeth. (9)

Patients that will be eligible for stripping will need to have a low caries risk, with good oral hygiene and with teeth of a triangular shape (which will allow us to gain more space while removing less of the enamel) (6).

1.3.2 Contraindications

However, patients presenting crowding of more than 8mm per arch (3), a high caries risk index, dysplasia or that have parallel adjacent surfaces are not eligible for treatment. In the case of parallel adjacent surfaces, the procedure might create the risk of having root contact, damaging the periodontium (6). Moreover, in unstable cases such as "poor oral hygiene, active periodontal disease, enamel hypoplasia, hypersensitivity to cold, high caries index and multiple restorations", IER will be contraindicated, as it could worsen the existing situation. Lastly, in rectangular shaped anterior teeth, round-shape premolars and large pulp chambers in young patients, we will avoid stripping as it might be complicated to establish a correct contact point (3,10).

1.4 Procedure steps

IER can be divided into 6 steps:

1. The treatment needs to start with a complete diagnosis and comprehensive planning. Study cast measurements and calibrated radiographies are obtained in order to plan the outcome and assess the amount of enamel that can be removed.
2. We then want to expose the interproximal surfaces in order to gain visibility and mechanical access. The teeth need to be perfectly aligned so we will restore the contact points through a phase of leveling and aligning.
3. Protection of the soft tissue.
4. We can then continue with the removal of interproximal enamel by manual or mechanical technique using a water or air cooling technique.
5. Finishing and polishing of the enamel surface (with a cone shaped triangular diamond bur). Orthophosphoric acid can be used at 37% to smooth the surface. Sealants can be used after the polishing.
6. The last step is to remineralize the enamel through the application of fluoride through rinses or topical solutions (2,3).

Additional recommendations include: never starting the procedure before bonding attachments are placed, don't strip all teeth in one appointment and perform it from posterior to anterior (8).

1.5 Interproximal reduction techniques and their main indications

In order to perform enamel reduction, 3 main techniques are currently being described: diamond coated strips (held manually or motorized), diamond coated discs (motorized) and the air rotor stripping (ARS) technique (motorized). Burs, thin blades and chemical stripping are also being used by practitioners. The technique will be chosen depending on the degree of crowding of each case (3). (Figure 4.)

1.5.1 Abrasive diamond-coated metal strips

Abrasive metal strips are mainly used for anterior reduction, in cases of mild crowding when little enamel has to be stripped. They can be held by the practitioner, through the Mathew hemostat or with a special holder, in a bucco-lingual movement. They can also be motorized when used with special low speed handles and an oscillatory movement. The strips are diamond coated, single or double sided and can have a medium or fine grit (3).

These metal strips include the "Intensive Ortho-strips", which are considered an alternative to ARS, which will be further reviewed. They are semi-flexible strips, used with a special low piece handle, in antero-posterior movements. Three types of strips exist. The first ones are the thin ones. They remove 0,140 to 0,160mm of enamel and are indicated to separate the contact point or to polish. The second ones are medium ones. They remove 0,270 to 0,330mm of enamel and are indicated for enamel reduction and teeth contouring. The last ones are called coarse. They remove 0,370 to 0,560mm of enamel and are indicated for the main enamel reduction, in cases of crowding. These can also be used to remove composite resin and amalgam (6).

1.5.2 Abrasive diamond-coated disk

Abrasive diamond-coated discs resemble the strips. They are also with single or double sided coating, and exist in different sizes, thicknesses and grits. They are used with a hand piece or with the Tuverson method (figure 3.) and require special handles that generate a speed of 4000-20,000 rpm, in order to obtain the necessary torque, as conventional low speed don't. They also need a special cover, shielding the soft tissues from the ¾ of the disc (6).

Figure 3. IPR performed on posterior teeth with the modified Tuverson technique. Use of **A**, extrafine diamond disk with a contra-angle and Eliott separator; **B** and **C** cone shape triangular diamond bur. (9)

1.5.3 Burs

Burs can also be used for enamel stripping. They should have a safe tip and can be placed on air rotor or electric handpiece to remove interproximal enamel (6).

1.5.4 The ARS method

Air rotor stripping or ARS was first described by Sheridan and is used to create space in buccal segments. It is performed with a safety-tipped bur that prevents the creation of furrows. The procedure is the following: one starts the enamel stripping with a safe tipped cross cut fissure carbide 699L bur. Next for smoothening and contouring, one uses a 100 micron medium-grit, tapered diamond bur. Then, for extra polishing a 30 micron fine grit, tapered diamond bur is used. The procedure is finished by polishing with a 15 micron extra-fine grit tapered diamond bur (3,6).

1.5.5 Intensive ProxoShapes

Intensive proxo shapes are flexible thin blades that remove very little amounts of enamel in between the molars. They are used to create space for banding (3).

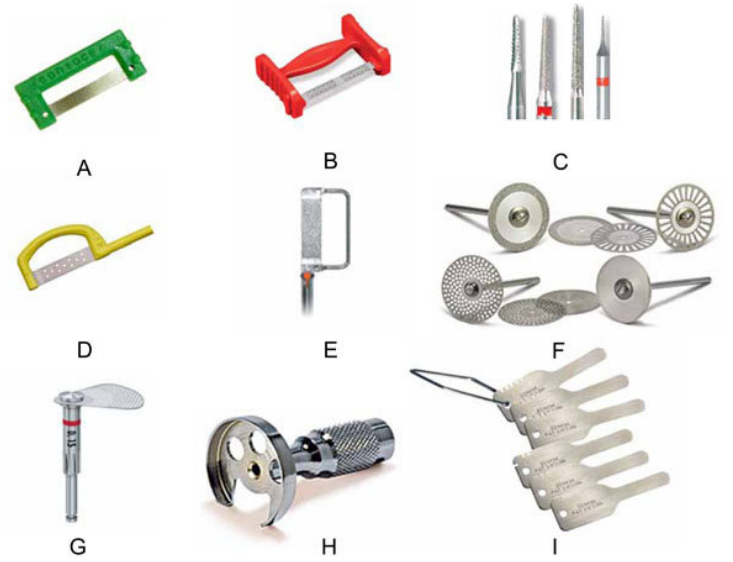

Figure 4. Available accessories for IPR. (A) Dental Strip, (B) Dental Strip, (C) Safe tipped ARS burs, (D) Interproximal Strip, (E) Intensiv Ortho Strip System, (F) Diamond Discs, (G) Oscillating segment disc, (H) Diamond Disc Safety Guard, (I) Calibrated Gauge Set. (2)

1.5.6 Chemical stripping

Another method to produce enamel stripping is through the use of 37% orthophosphoric acid on enamel. This etching will facilitate mechanical stripping.

1.5.7 Gauges

In order to know how much enamel we are reducing, calibrated gauges are available to the practitioner. They are precise to one tenth of a millimeter and can be placed in the

interproximal space. They allow accurate control over how much enamel is being removed (11).

1.6 Polishing

After performing the enamel stripping with the various techniques previously mentioned, it is common to polish the surface of the enamel in order to decrease the surface's roughness. Different authors recommend various techniques. The main ones being described are polishing discs, medium diamond burs and flexible strips dipped into 37 % orthophosphoric acid (8).

1.7 Protection of the tissues

In order to perform a safe enamel stripping, protection of the soft tissue is necessary. Various methods are described and can be employed by the practitioner.

1.7.1 Protection of the soft tissues

To protect the soft tissues, the practitioner can perform absolute isolation by placing a rubber dam. When using discs, a shield that covers ¾ of the discs can be used to protect the cheek and the tongue. Burs used for interproximal stripping present a safe tip that allows to create a ledge on the enamel, avoiding iatrogenesis to the gingiva. Moreover, to protect the gingiva from laceration, a 0,20-0,40" brass or steel indicator wire (open spring form) should be placed under the contact point to indicate the limit of tissue to be removed (6,11). Lastly, a separator can be used to retract the soft tissues and improve access to the interdental area that needs to be stripped (Figure 5.) (3).

Figure 5. Showcase of the use of a separator and modified Tuverson technique for IPR. (3)

1.7.2 Protection of the interdental tissue

It is also important to assure that no harm is produced on the adjacent teeth that are not being stripped. In order to protect them, one can use a disk guard, an indicator wire or place wooden wedges (Figure 6.). If diamond coated discs are being used, (3).

Figure 6. Wooden wedges placement before the start of the IPR procedure. (8)

1.7.3 Protection of the pulp

Damage to the pulp by overheating can happen during IPR, especially when using a high speed handpiece with tungsten carbide burs in lower incisors. When the pulp temperature rises above 5,5ºC, it can leave irreversible damage. In order to avoid this overheating, cooling techniques can be employed such as air or water spray (3,6).

1.8 Remineralization techniques

After performing enamel stripping, various remineralizing agents can be used in order to restore the enamel health, preserve its integrity and prevent the appearance of caries and plaque accumulation. The main agent described was a fluoride varnish, which is a fluoride concentrate that comes at a concentration of 1000 to 56,300 ppm, depending on the brand, that is placed on the teeth after the procedure is performed (12). Its main action is to replace calcium ions, present in the calcium hydroxyapatite of the enamel tissue, by fluoride ions, in order to form fluorohydroxyapatite. Fluorohydroxyapatite or fluoridated hydroxyapatite has a lower demineralization pH, and so a higher resistance to acid attacks and so decreases the risk of caries (12). Moreover, recent studies have shown interest in casein phosphopeptide amorphous calcium phosphate (CPP-ACP). This compound has proven effective against demineralization by maintaining calcium and phosphate plaque levels, and enhancing the remineralization process like fluoride. Furthermore, carbonate-hydroxyapatite nanocrystals (CHA) can act as a "biomimetic mineral coating" that coats the enamel. When added with zinc ion to toothpaste they give a cariostatic effect that is maintained on the long term (13).

1.9 Enamel thickness and dental anatomy

It is important to consider the dental anatomy and enamel's thickness to properly perform IPR and to know exactly how much tissue to remove and where to remove it. Various studies have been performed to establish guidelines on teeth's dimensions. In a study of 101 subjects, Yagci et Al. measured both mesial and distal aspects of the teeth as well as cervical, middle and incisal length, in order to obtain an average mean of enamel's thickness and crown dimensions (Figure 7, 8 and 9) (14).

Table 4: Comparison of mesial and distal enamel thickness						
Tooth	*n*	Mesial ET		Distal ET		*P*
		Mean	SD	Mean	SD	
Upper Centrals	202	1.03	0.32	1.05	0.63	0.95
Upper Laterals	202	1.06	0.24	0.98	0.61	0.019*
Upper Canines	202	1.14	0.23	0.99	0.21	<0.001***
Upper First Premolars	202	1.01	0.19	0.96	0.17	0.021*
Upper Second Premolars	202	0.98	0.17	1.03	0.18	0.003**
Lower Centrals	202	1.05	0.31	1.03	0.34	0.455
Lower Laterals	202	1.1	0.36	1.09	0.36	0.639
Lower Canines	202	1.22	0.4	1.14	0.35	0.015*
Lower First Premolars	202	1.25	0.29	0.98	0.2	<0.001***
Lower Second Premolars	202	1.21	0.24	1.03	0.2	<0.001***

ET: Enamel thickness; SD: Standard deviation; *P<0.05; **P<0.01; ***P<0.001

Figure 7. Average enamel's thickness in mesial and distal. (14)

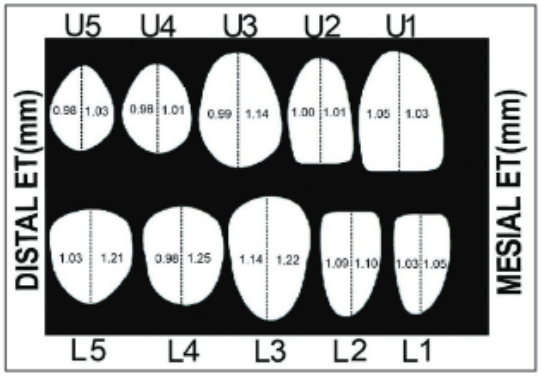

Figure 8. Graph summarizing average mesial and distal enamel thickness. From left to right: central incisor, lateral incisors, canine, first premolar and second premolar. U1-U5: upper maxilla, L1-L5: lower mandible. (14)

Table 3: Comparison of crown widths between right and left sides						
Tooth	*n*	Right Quadrant		Left Quadrant		*P*
		Mean	SD	Mean	SD	
Upper Centrals	101	8.57	0.58	8.56	0.62	0.916
Upper Laterals	101	6.42	0.57	6.43	0.55	0.923
Upper Canines	101	7.47	0.57	7.41	0.49	0.449
Upper First Premolars	101	6.48	0.51	6.56	0.44	0.225
Upper Second Premolars	101	6.32	0.55	6.44	0.52	0.107
Lower Centrals	101	5.33	0.71	5.36	0.69	0.754
Lower Laterals	101	5.8	0.48	5.82	0.47	0.639
Lower Canines	101	6.69	0.51	6.54	0.5	0.052
Lower First Premolars	101	6.73	0.61	6.58	0.52	0.07
Lower Second Premolars	101	6.9	0.55	6.77	0.6	0.11

SD: Standard deviation

Figure 9. Mean crown's width in right and left sides. (14)

Even if those tables appear as a helpful guide and give us an average idea about what to expect facing the patient, the practitioner has to take into account sexual and ethical dimorphism as well as individual variability.

Moreover, as previously mentioned not all teeth are eligible for treatment, based on their different shapes. Le Huche index is a helpful guide to know which teeth can be stripped based on the degree of divergence in the mesio-distal width at the level of the contact points and at the level of the cemento-enamel junction. A high index indicates a triangular shaped tooth which is ideal for treatment. On the contrary, a square shaped tooth equals a patient at risk of periodontal disease, as stripping it would cause the root's proximity (8).

1.10 Possible complications after enamel stripping

The possible complications after enamel stripping are still under discussion and many authors have diverse opinions on the matter (15). The main related complications of IER fall under the following categories: irreversible pulp damage, increased plaque accumulation, hypersensitivity, periodontal disease and a higher caries incidence. However the following authors: Crain and Sheridan, Zachrisson, Nyoyaard and Mobarak and Fillion argue that there is no direct correlation between enamel stripping and the occurrence of periodontal disease (3). Moreover one of the challenges faced while performing enamel stripping is the creation of furrows on the enamel surface that can lead to increased plaque formation (6).

1.11 Justification

Enamel stripping is becoming more and more part of the common practice as a way to increase the efficiency and long term maintenance of the treatment and improve the final esthetics. Moreover, there is an increased demand for the use of clear aligners such as Invisalign®, as patients consider it more aesthetic and less invasive. IER then comes as a viable solution to extraction or expansion in those borderline cases, in order to be able to use clear aligners. However, it is an irreversible procedure and can have deleterious effects

on the enamel tissue and periodontal health if performed incorrectly. Therefore, it is important to dive into the subject and understand the different factors that come into play when realizing a cautious, yet effective, enamel stripping procedure. A good review on the indication of enamel as a part of the orthodontic treatment is necessary.

1.12 Research question

Our research question was defined using the PICO format (Table 1.):

Table 1. Pico question

P	Patient: all orthodontic patients with orthodontic treatments
I	Intervention: enamel stripping
C	Comparison: different techniques used to perform the enamel reduction
O	Outcome: benefit of each technique in preserving the enamel health

1.13 Hypotheses

Hypothesis: It is suspected that the use of mechanical stripping followed by polishing and in combination with a remineralization post-treatment is the safest way to perform interproximal stripping, in order to preserve the health of the enamel tissue and to prevent the risk of complications.

Null hypothesis: There is no difference between manual and mechanical stripping and polishing and remineralization don't influence the health of the enamel post interproximal reduction.

2. OBJECTIVES

2.1 Main objective

- The main objective of our research will be to determine which is the safest way to perform enamel stripping.

2.2 Secondary objectives

- The first objective is to compare manual and mechanical techniques for interproximal reduction and evaluate which results in the smoothest enamel.

- The second objective is to determine the need for polishing after performing IPR and which technique provides the best polishing.

- The third objective is to evaluate the necessity of remineralization techniques post enamel stripping.

- The fourth objective is to define safe margins on how much enamel can be removed when performing interproximal stripping.

3. MATERIALS AND METHODS

To conduct the review, an electronic research was performed using the following databases: Medline Complete, ScienceDirect, Pubmed.

Keywords: "Dentistry", "Interproximal enamel reduction", "Enamel stripping", "Air-rotor stripping", "Orthodontics".

Search equation: based on those keywords, the following search equation was established: ((enamel) AND (interproximal)) AND (reduction)), and 26 articles were chosen, based on the following criterias (Table 2.):

Table 2. Inclusion and exclusion criterias

Inclusion criteria	Exclusion criteria
Articles on enamel interproximal stripping	Information not relevant to the topic
Full text available	Only abstract or summary available
Systematic Reviews, Clinical trials, In vivo studies, In vitro studies	Case descriptions
Articles in English, Spanish or French	Articles dated of more than 20 years
Articles published within the last 20 years	Studies including less than 20 subjects
Studies including more than 20 subjects	

4. RESULTS

For the bibliographical research 1688 articles were found. 213 articles were retained after screening duplicates and applying exclusion criterias. After reading the titles and abstract 51 articles were selected and after reading the full texts, 26 articles were included in the literature review (Figure 10.).

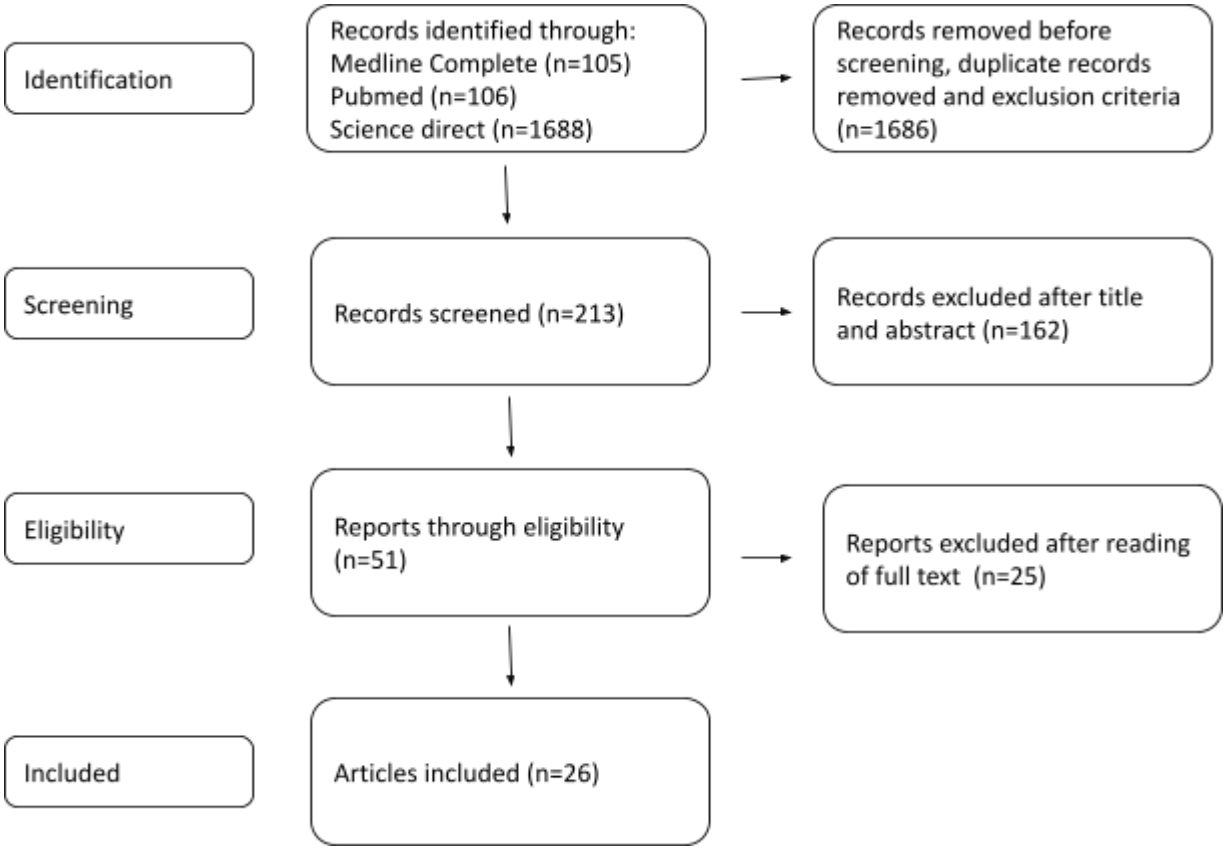

Figure 10. Flow chart

The results are presented in the following table (Table 3.)

Table 3. Comparison of enamel reduction techniques, polishing, remineralization techniques and enamel margins available for removal.

Author, Year	Study type	Sample	Outcome assessed	Main result
Livas et al. 2013, (2)	Literature review	42 articles	-Surface roughness -Prevention of stripping heat -Efficiency of remineralization techniques	-Finer grain size Sof-lex discs provide better polishing, reducing iatrogenic enamel furrows -Water and air cooling prevent iatrogenic effects to the enamel -No significant benefit of the use of fluoride post stripping in the remineralization of the enamel
Rossouw and Tortorella, 2003, (1)	Literature review	63 articles	-Safe enamel margins -Surface roughness	-50% of enamel can be stripped -Tooth size analysis provides higher success to treatment outcome -37% orthophosphoric acid encourages enamel auto-remineralization + enhanced by the use of fluoride agents
Georgiadis et al, 2015, (6)	Literature review	32 articles	-Polishing -Comparison of IPR techniques -Enamel margins -Orthophosphoric acid -Fluoride application	-Sof-lex discs provide the best polishing, leaving the enamel as if untouched -Metal strips can provide better access over discs regardless of the tooth morphology -Electric handpiece provide better speed control than air rotor when burs are used -Strips and discs allow 50% of enamel reduction while ARS allows 1/3 decrease -0,5mm can be removed at each contact point -Hudson: 0,2 mm for each central incisor; 0,25 mm for lateral incisors; 0,3 mm for canines -Max 0,4 mm at each anterior teeth lets us can up 4 mm of space -Use of 37% orthophosphoric acid increases enamel remineralization -Aim to leave a greater contact area

				to reduce conical shape and decrease plaque accumulation -Finer diamond tools leave furrows of smaller depth than coarse grain -An 8-blade tungsten carbide bur in addition to a Sof-Lex disc result in the best polishing, leaving the surface smoother than unstripped teeth -Local fluoride compound should be applied to reduce caries risk
Rossouw and Tortorella, 2003, (16)	Pilot study	32 bovine teeth	-Comparison of mechanical and chemical enamel reduction techniques to evaluate residual smoothness	-The application of maleic and phosphoric acid to polish the enamel surface after stripping resulted in a smoother surface.
Meredith et Al. 2017, (17)	In vitro study	64 human premolars	-Enamel's nanotopography after the performance of most common IPR instruments -Effects of polishing post IPR	-From roughest to smoothest surface obtained: diamond-coated burs, diamond-coated strips, diamond coated discs. -Smoother surface post IPR than untreated enamel was obtained after the use of Sof-lex polishing discs
Jarjoura et Al. 2006, (18)	Cohort study	40 patients	-Benefit of fluoride application post IPR	-Topical fluoride application post ARS does not provide any benefit in patients already exposed to fluoride-containing water and toothpaste
Pereira et Al. 2014, (19)	In vitro study	78 proximal surfaces of 39 extracted human teeth	-Pulp chamber temperature changes during IPR using stripping discs and handheld strips	-In both methods, the pulp temperature increase did not surpass the iatrogenic value of 5,5ºC -Discs showed a greater temperature increase than handheld metal strips
Gazzani et Al. 2019 , (20)	In vitro study	12 human premolars	-Efficiency and effects on enamel of mechanical vs manual IPR techniques	-Better control was found in oscillating diamond strips compared to manual IPR resulting in a more smoother enamel surface

Fernandes et Al. 2011, (21)	In vitro study	40 extracted human mandibular molars	-Mean enamel thickness on the mesial and distal wall of molars. -Existence of sexual dysmorphism -Validity of morphological imaging when determining the enamel thickness for treatment planning.	-The enamel showed greater width on the distal surface: 1,46mm on the right side and 1,44mm on the left side compared to mesial: 1,40mm on the right and 1,35mm on the left -Crow dimensions were greater in men but mainly present in dentin thickness -Radiographies, tomography and cone beam computed tomography showed positive results for clinical assessment, yet the patient's individuality needs to be considered for proper treatment planning.
Zachrisson et Al. 2011, (9)	Cohort	43 patients that received IPR in their premolars and 1st molars	-Caries risk post IPR treatment in 4-6 years follow up	-IPR does not increase caries incidence. No harm was found in teeth and supporting structures
Danesh et Al. 2020, (22)	In vitro study	65 extracted teeth	-Remineralization post IPR -Link between the enamel roughness and acid penetration depth -Manual vs mechanical systems: manual metal strips, mechanical oscillating segment discs, safe tipped bur kit, ortho strips	-Polishing is essential post IPR treatment and shows less enamel roughness than untreated enamel. -Remineralization is necessary to reduce caries risk (as it reduces the depth of acid penetration). -The interproximal enamel roughness was reduced best with oscillating IPR systems and with the manual IPR method (new metal strips).
Yagci et Al. 2021, (14)	In vivo study	101 CBCT records	-Safe enamel margins: thickness and limitation -Sexual dysmorphism	-Each tooth had a unique enamel thickness in mesial and distal -Enamel's thickness at the middle 1/3 was bigger on the mesial side for mandibular canines + premolars, and for maxillary lateral incisors + canines +1st premolars

				-The enamel was thicker in men in mesial of maxillary laterals compared to women. In mesial of mandibular first premolars it was thicker in females than males.
Gomez-Aguirre et Al. 2022, (15)	Systematic review	36 articles	-Effect of IPR on the enamel	-No increase of caries, periodontal affectation, dental sensitivity and demineralization were caused by IPR
Hellak et Al. 2015, (23)	In vitro study	66 extracted upper front teeth	-Correlation between demineralization and different stripping methods (Profin Directional System®, Intensiv ProxoStrip®, OS discs®, ARS Safe-Tipped Bur Kit® and Ortho-Strips Set®) -Importance of stripping post IPR	-ARS resulted in the biggest demineralization -Polishing after the enamel reduction didn't improve the amount of demineralization post IPR
Macha et Al. 2010, (24)	In vitro study	40 extracted sound bicuspids	-Enamel thickness -Safe margins for stripping	-50% proximal reduction can be performed to gain 7mm of space -Importance of radiographs and individual susceptibility to plan amount to be reduced -Proximal enamel ranged from 1,08 to 1,29mm in width -0,4 to 0,5mm is the suggested limit for IPR
Johner et Al. 2013, (25)	In vitro study	180 extracted premolars	-Accuracy of 3 IPR techniques: hand pulled strips, oscillating segmental discs, motor driven abrasive strips to reduce a predetermined enamel amount	-The mean amount of stripped enamel was less than the desired amount in all 3 methods used
Arman et Al. 2006, (7)	In vitro study	120 deciduous and permanent teeth	-Compare different stripping methods and evaluate the end roughness: stripping discs, diamond-coated metal strips, 37 % orthophosphoric acid (chemical stripping) -Polishing benefits	-The roughest surfaces were produced with metal strips and chemical stripping. -The use of Sof-Lex discs to polish the enamel surface after stripping showed best results to obtain a smooth surface

Lapenaite et Al. 2014, (3)	Systematic review	31 articles	-Comparison of various IPR methods and their effect on enamel -Safe enamel margins	-Chemical stripping and ARS without polishing resulted in the roughest enamel -Diamond-coated disk with Sof-Lex polishing showed the best results -A straight line from cervical to occlusal can be used as a guide to show the dentin's limits. -Enamel is thinner in distal
Chudasama et Sheridan, 2007, (11)	Review	16 articles	-Margins -Polishing -Fluor remineralization	-0,5mm of enamel per proximal surface can be removed -35% orthophosphoric acid is beneficial to further polish the enamel (fine abrasive strip coated with ortho acid) -Remineralization with fluor is deemed necessary for proper enamel strength
Danesh et Al. 2007, (26)	In vitro study	55 extracted teeth	-Polishing -IPR techniques	-Polishing is essential to decrease the surface roughness -Oscillating systems were deemed to perform best
Almansouri et Al. 2023, (27)	In vitro study	75 extracted premolars	-Remineralization effect of different polishing agents after IPR: fluoride gel, resin infiltration material, casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) containing varnish	-The varnish worked in strengthening the enamel and helping it resist to acidic attacks
Boneti et Al. 2014, (13)	In vitro study	21 extracted lower incisors	-Qualitative evaluation of zinc-carbonate hydroxyapatite (Zn-CHA) toothpaste compared to fluoride toothpaste	-Zn-CHA appears to be a good way to counter the demineralization in enamel after IPR
Ben Mohimd et Al. 2019, (12)	In vivo study	14 premolars from 6 patients	-Fluoride application benefit on stripped teeth	-Fluoride varnish contributes to protect the enamel health

5. DISCUSSION

After careful reading of the literature, it was established that many guidelines are currently available in order to perform enamel stripped in orthodontics. We will see agreement and divergences that authors share, in order to find out which are the best recommendations to perform enamel stripping in the most efficient and safest way possible. In this part of the discussion, we will first take a look at advantages and disadvantages of the existing techniques. We will then go in depth regarding polishing, to know if it is judged necessary. We will continue by analyzing the necessity of fluoride application post stripping. Lastly, we will determine what is the enamel's width that is available and deemed safe for interproximal stripping.

5.1 Manual vs Mechanical stripping

As previously mentioned in the introduction, various methods exist in order to realize the stripping procedure. The main goal is to have a technique that allows easy access to the interproximal surface and good hand control over the instrument. We want to use instruments that result in the smoothest enamel possible, as we saw that rough surfaces lead to plaque accumulation, periodontal problems and higher caries risk. Moreover, a crucial characteristic to look for in the different techniques is the precision of the enamel removal. As the margins are small, millimeters matter when removing the enamel and the tools used should be very precise.

5.1.1 Site accessibility

In 2015, in a literature review of 32 articles, Georgiadis et Al. determined that in order to access the stripping site, no matter the anatomy of the teeth, metal strips permitted better access compared to discs. (6)

5.1.2 Precision

In 2015, in a literature review of 32 articles, Georgiadis et Al. determined that when using burs, the practitioner had better control using an electric handpiece compared to ARS. (6)
In 2019, in an in vitro study, Gazzani et Al. performed IPR on 12 human premolars in order to compare oscillating and manual strips. They came to the conclusion that the oscillating diamond strips provided better control which also resulted in smoother enamel. (20)
In 2013, Johner et Al. studied 180 extracted premolars in an in vitro study. They compared the accuracy of 3 IPR techniques: hand pulled strips, oscillating segmental discs and motor driven abrasive strips to reduce a predetermined enamel amount. They came to the result that the mean amount of stripped enamel was less than the desired amount in all 3 methods used (25).

5.1.3 Surface roughness

In 2017, in an in vitro study, Meredith et Al. analyzed, using atomic force microscopy, 64 enamel slabs that were cut from human premolars and treated with discs, strips and diamond burs. They came to the conclusion that Diamond coated discs resulted in the smoothest surfaces and that the burs left the roughest enamel (17). Danesh et Al. also came to the same conclusion in a 2020 in vitro study, where they compared mechanical oscillating segment discs, manual New Metal Strips, a safe-tipped bur kit, and ortho-Strips, on 65 extracted teeth. The discs and the new metal strips performed in achieving the smoothest surface (26).
Furthermore, in 2006, Arman et Al. compared, in an vitro study on 120 deciduous and permanent teeth, stripping discs, diamond-coated metal strips and chemical stripping (with 37 % orthophosphoric acid) and evaluated the end roughness of the enamel. They saw that roughest surfaces were produced with metal strips and chemical stripping (7).
Lapenite et Al. winded up to the same conclusion in their systematic review, agreeing that chemical stripping and ARS without polishing resulted in the most uneven enamel (3).

5.1.4 Temperature effect on the pulp

It is important to keep the intracoronal pulp temperature under control when performing enamel stripping. We saw that an increase in pulp temperature can cause iatrogenesis to the tooth. Air and water cooling are part of the common procedure to regulate the temperature during IPR. In 2014, Pereira et Al. conducted an in vitro study on 78 proximal surfaces of 39 extracted human teeth in order to analyze which methods showed the smallest temperature increase. They determined that if the temperature surpassed 5,5º then damage would be produced to the tooth. They compared handheld metal strips and discs. Both did not reach that value but the metal strips resulted in a smaller increase of the temperature. (19)

Moreover, in 2015, Hellak et Al. found that ARS resulted in the biggest demineralization, when they performed an in vitro study on 66 upper front teeth, in comparison with five polishing systems with different IPR techniques. (23)

Through the analysis of these articles, we can start to understand that discs appear to show the most advantages: they provide better control and result in a smoother enamel surface at the end of the stripping procedure. Metal strips come second as they allow easier access to the stripping site and lead to less pulp temperature increase, however they showed worse end smoothness. Newly developed metal strips appear to have promising results.

5.2 Polishing

As mentioned, while the main goal of interproximal stripping is to gain space in the arch for teeth alignment, one of the most important objectives the orthodontist should have in mind is to achieve the smoothest enamel possible. The risk when performing IPR is to create a rough enamel with furrows that retain plaque and increase the chance of developing periodontal disease and caries. Moreover, a smooth surface allows better remineralization of the enamel, meaning stronger and healthier teeth. We saw that the current methods used, especially oscillating discs, can lead to a smooth enamel, authors have various opinions on whether polishing is necessary and on which techniques result in the best polishing.

5.2.1 Polishing need and instruments performance

In 2013, Livas et al. in a literature review of 42 articles, determined that the finer the size of the grain was being used, the better the polishing and the least iatrogenic enamel furrows were created (2).

Georgiadis et Al. found that Sof-lex discs provided the best polishing. They concluded that the surface was as smooth as untouched enamel if the enamel was polished. They also saw that finer diamond tools compared to coarse grain led to smaller furrows. In order to achieve the best polishing, they recommend the use of an 8-blade tungsten carbide bur in addition to a Sof-Lex disc (6).

Danesh et Al. also agreed to say that polishing is necessary to the IPR procedure and it led to less enamel roughness than untreated enamel (26).

Arman et Al. as well as Meredith et Al. in both their in vitro study and Lapenaite et Al. in a 2014 systematic review of 31 articles, concluded that Sof-Lex discs were the best tool to polish the enamel after stripping and showed best results to obtain a smooth surface (3,7,17).

However, when conducting their in vitro study previously mentioned, Hellak et Al. came to the conclusion that polishing didn't improve the amount of demineralization post IPR. By comparing five polishing techniques, they decide that they could not classify polishing as helpful in terms of enamel remineralization and that the practitioner should rather take each patient's individuality into account (23).

5.2.2 Orthophosphoric acid

In 2003, Rossouw and Tortorella determined in a literature review of 63 articles that 37% orthophosphoric acid clearly helped the auto-remineralization of the enamel (1).

Also in 2003, they conducted a pilot study on 32 bovine teeth to test the effect of chemical polishing on the enamel. They performed IPR mechanically and chemically and later analyzed the enamel's surface with the aid of electron microscopy. They concluded that the

application of maleic and phosphoric acid to polish the enamel surface after IPR left a smoother surface (16).
Chudasama et Sheridan, in a 2007 review of 16 articles agreed to say that fine abrasive strips coated with 35% orthophosphoric acid were useful for the polishing (11).
Georgiadis et Al. also agreed to say that the use of 37% orthophosphoric acid increased enamel remineralization(6).

Through the analysis of these different articles and taking into account each author's point of view, we can agree to say that polishing is an essential step of the IPR procedure and that it does result in a smoother enamel. Moreover, most authors seem to conclude that the use of 37 % orthophosphoric acid after the use of Sof-lex polishing discs are the keys to the most efficient polishing.

5.3 Remineralization techniques

Following polishing, the last step of IPR would be to apply a local agent to help remineralize the enamel. However, the necessity of that step is the source of debate.

Rossouw and Tortorella, in their review, argue that fluoride agents enhance the enamel remineralization (1). This is supported by Georgiadis et Al. as well as Chudasama et Sheridan, that confirm that a local fluoride compound should be applied to reduce caries risk (6,11).
Moreover, Danesh et Al. conducted an in vitro study in 2020 over 65 extracted teeth to understand the relation between the acid depth penetration and the quality of the enamel's surface. They came to the result that in order to reduce the caries risk, remineralization techniques are necessary (22). Furthermore, in a 2019 study, Ben Mohimb et Al. conducted an in vivo study on 6 patients, evaluating 14 stripped premolars. Their goal was to compare teeth that were exposed and not exposed to a fluoride varnish after IPR. After analyzing their surface with Dispersive Energy Spectroscopy, they came to the conclusion that a fluoride varnish can be valued as beneficial for the remineralization of enamel health (12).

However, Livas et Al, in their review previously mentioned, believe that there is no significant benefit to the use of fluoride (2). This thought was shared by Jarjoura et Al. in a 2006 cohort study on 40 patients. They clinically and radiographically analyzed the patient's teeth over 6 years to determine the incidence of caries after having performed IPR. They came to the conclusion that the topical fluoride application did not provide any benefit in patients that were already exposed to fluoride-containing water and toothpastes (18).

To put in perspective all of the previous data, we can take into account that many authors came to the conclusion that enamel stripping does not increase the risk of caries. The authors previously mentioned: Livas et Al, Rossow and Tortella, Georgiadis et Al and Jarjoua et Al. al came to the same conclusion that stripping does not exacerbate caries formation (1,2,6,18). Moreover, in 2011, Zachrisson et Al came to the conclusion after they conducted a cohort study over 6 years that IPR does not increase caries incidence (9). Lastly, in 2002, Gomez-Aguirre et Al. in a systematic review also came to the same conclusion that no increase of caries and no demineralization were caused by stripping (15). This could make us believe that remineralization is not deemed necessary by authors as preexisting demineralization does not happen. However, we could argue that it could be seen as a great preventive tool that contributes to long lasting enamel health and that doesn't cause any harm to it, even if necessity is not well understood.

Nevertheless, in a very recent study dating from 2023, Alamansouri et Al paid greater attention to the necessity of using fluoride after IPR to help the enamel resist acidic attacks. By analyzing previous studies, they came to the conclusion that updated protocols, to help the prevention of caries formation after IPR, are lacking. Indeed, the caries formation process has to take into account the cariogenic biofilm of the individual, his access to dental checkups and fluoridated water and his personal oral hygiene. In order to update the information, they compared the effect of a fluoride gel, a resin infiltration material and a casein phosphopeptide-amorphous calcium phosphate (CPP-ACP known as MI varnish) containing varnish on 75 premolars. They came to the conclusion that the MI varnish was the only one that successfully helped remineralize and protect the enamel (27).

On a broader spectrum, Boneti et Al conducted an in vitro study, in 2014 on 21 premolars, in order to compare the use of zinc-carbonate hydroxyapatite (Zn-CHA) and fluoride in toothpaste to remineralize the teeth after enamel reduction was performed. Zn-CHA demonstrated greater remineralization and was deemed a good alternative to fluoride (13). One could consider this an interesting approach to reinforce stripped enamel in the long term.

Overall, we cannot clearly state that remineralization through the use of topical fluoride is essential while performing the IPR procedure. We have to consider individuals' susceptibility to caries and their oral hygiene, as well as if the patients are already exposed to fluoride through their water consumption and their daily use of toothpastes and mouthwashes. More in vivo studies are needed to help establish a proper remineralization protocol. Overall, an MI varnish seems to be the best agent to strengthen enamel after IPR.

5.4 Safe enamel margins available for IPR

The last and most important thing to consider when performing IPR is how much enamel can be removed on each tooth. We previously saw that some authors have established tables to use as guidelines to know the enamel's dimensions and that the use of radiographs as well as considering individual's susceptibility is essential for the treatment planning. Knowing these margins, some guidelines can be established on how much enamel is available for interproximal reduction in order to gain space in the arch for teeth alignment.

Rossouw and Tortorella as well as Chudasama et Sheridan, in their literature reviews, deduced that 50% of enamel can be stripped (1,11). Georgiadis et Al, also agree that 50% of the enamel can be stripped at each contact point. Resulting. They specify that 0,2mm for each central incisor; 0,25mm for lateral incisors; 0,3mm for canines are available for stripping (6). In 2010, Macha et Al conducted an in vitro study on 40 premolars, and also

came to the conclusion that 50% of the enamel can be subject to IPR, giving a limit of 0,4 to 0,5 millimeters to be stripped away (24).

Fernandes et Al. in 2011, directed an in vitro study on 40 molars. They concluded that the enamel was wider on the distal side of the teeth, that sexual dysmorphism was mainly present in the dentin and that the use of x rays (radiographies, tomography and cone beam computed tomography) could be helpful in determining how much enamel can be removed on each patient (21).

In 2021, Yagci et Al. tested out the existence of sexual dysmorphism and the enamel thickness limitation for IPR in an in vivo study using 101 CBCT records. They concluded that each tooth has a unique enamel thickness and that no sexual dysmorphism could be clearly stated as it was different for each tooth. However they noticed that the enamel was thicker on the mesial side for upper lateral incisors, canines, 1st premolars, and for lower canines and premolars. Concluding that we can suspect greater thickness on the mesial side of most teeth (14).

Lastly, in their systematic review of 2014, Lapenaite et Al. observed that enamel is thinner on the distal wall of the teeth and that in order to know how much enamel to remove while performing IPR, a straight line from cervical to occlusal could be drawn and used as a guide to know the dentin's limits (3).

To conclude, it appears that all authors reviewed agree that 50% of the enamel is available for stripping. Most of all it is important to take into account that each tooth has a different anatomy and that the width of the enamel will depend on each individual. No major difference was found between men and women regarding the enamel's width. However, authors disagreed on which wall is thicker between mesial and distal. Overall, taking each individual into account when treatment planning seems to be the key to a safe enamel stripping. X rays are a very good tool that help us estimate how much enamel is available for reduction.

6. CONCLUSION

After the previous considerations we can conclude that:

- To answer our main objective: the safest way to perform enamel stripping is through the use of mechanical diamond discs followed by polishing with Sof-lex discs and the application of 37% orthophosphoric acid. The practitioner can remove up to 50% of the enamel. It is suggested to use a casein phosphopeptide-amorphous calcium phosphate varnish at the end of the procedure.

- Between manual and mechanical techniques, mechanically operated diamond discs appear to be the technique of choice and result in the smoothest enamel.

- Polishing is an essential step to include at the end of the enamel reduction procedure. The best polishing is obtained after the use of Sof-lex polishing discs followed by the application of 37% orthophosphoric acid on the interproximal surfaces.

- A clear conclusion cannot be drawn on the necessity of remineralizing techniques after stripping. Individual's susceptibility, oral hygiene and daily fluoride exposure seem to be more important factors, than post-treatment fluoride application, to preserve the enamel's health. The use of a casein phosphopeptide-amorphous calcium phosphate varnish is the most helpful to protect the enamel.

- The maximum amount of enamel that can be removed for interproximal enamel reduction is 50%, taking into consideration that the enamel has different thicknesses depending on each tooth and each individual.

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