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SYSTEMATIC REVIEW

Proximal enamel thickness quantification in orthodontics for interproximal reduction: A systematic review

Cuantificación del espesor del esmalte proximal en ortodoncia para la reducción interproximal: una revisión sistemática

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ABSTRACT

Background: Interproximal enamel reduction is a valuable procedure in orthodontics used in several conditions, however, not knowing the average value of proximal enamel thickness might lead to excess enamel removal and consequently to adverse effects.
Objective: The objective of this systematic review is to expose the average proximal enamel thicknesses found in the literature, and the differences that might be found between different ethnicities and age groups.
Search Methods: 5 electronic databases were used to perform the search. Representative keywords comprised of “enamel”, “thickness”, “orthodontics” “proximal thickness” and “quantification”; different combination of these keywords with truncation, and medical subject headings (MESH) were used.
Selection Criteria: In vitro and in vivo studies, where the quantification of the proximal enamel thickness of the mesial and distal sides were evaluated independently.
Data Collection and Analysis: The PICO model was used to evaluate and select the in vitro and in vivo studies. ROBINS-I tool was used to assess the risk of bias of non-randomized clinical studies and a modification of Cochrane risk of bias tool was implemented for the in vitro studies. The quality of evidence and results were evaluated using The Joanna Briggs Institute (JBI) Critical Appraisal checklist tools for Quasi-Experimental Studies.
Results: Literature search identified 3298 records from 5 databases. Ultimately, nine eligible studies were included in the review.
Conclusions: The proximal enamel thickness increases as we move distal through the arch and is greater on the distal side compared to the mesial side of each individual tooth. Additionally, there is no difference in the proximal enamel thickness between genders but there is between ethnicities.

KEYWORDS
Interproximal reduction; enamel thickness; orthodontics; systematic review.

RESUMEN

Antecedentes: La reducción del esmalte interproximal es un procedimiento valioso en ortodoncia utilizado en varias condiciones, sin embargo, no conocer el valor promedio del espesor del esmalte proximal puede conducir a una eliminación excesiva del esmalte y, en consecuencia, a efectos adversos.
Objetivo: El objetivo de esta revisión sistemática es exponer los espesores promedio de esmalte proximal encontrados en la literatura y las diferencias que se pueden encontrar entre diferentes etnias y grupos de edad.
Materiales y métodos: se utilizaron 5 bases de datos electrónicas para realizar la búsqueda. Palabras clave representativas compuestas por "esmalte", "grosor", "ortodoncia", "grosor proximal" y "cuantificación"; Se utilizaron diferentes combinaciones de estas palabras clave con truncamiento y encabezados de temas médicos (MESH).
Criterios de Selección: Estudios in vitro e in vivo, donde se evaluó de forma independiente la cuantificación del espesor del esmalte proximal de los lados mesial y distal.
Recopilación y análisis de datos: se utilizó el modelo PICO para evaluar y seleccionar los estudios in vitro e in vivo. Se utilizó la herramienta ROBINS-I para evaluar el riesgo de sesgo de los estudios clínicos no aleatorizados y se implementó una modificación de la herramienta Cochrane de riesgo de sesgo para los estudios in vitro. La calidad de la evidencia y los resultados se evaluaron utilizando las herramientas de lista de verificación de evaluación crítica del Instituto Joanna Briggs (JBI) para estudios cuasi-experimentales.
Resultados: La búsqueda bibliográfica identificó 3298 registros de 5 bases de datos. Finalmente, se incluyeron nueve estudios elegibles en la revisión.
Conclusiones: El grosor del esmalte proximal aumenta a medida que avanzamos distalmente a través del arco y es mayor en el lado distal en comparación con el lado mesial de cada diente individual. Además, no hay diferencia en el grosor del esmalte proximal entre géneros, pero sí entre etnias.

PALABRAS CLAVE
Reducción interproximal; espesor del esmalte; ortodoncia; revisión sistemática.

CLINICAL RELEVANCE

Interproximal reduction is a procedure used daily by orthodontists. This procedure consists of wearing down a percentage of the interproximal enamel to achieve orthodontic objectives.

However, since enamel is a tissue that does not regenerate, it is vital to be conservative, since if the width of said tissue is not taken into consideration, dentin could be reached, causing adverse effects. Therefore, this systematic review provides evidence on the average thickness of interproximal enamel for each dental unit, since in this way the clinician can infer how much to reduce on each tooth based in evidence, so adverse effects can be kept to a minimum.

INTRODUCTION

Interproximal enamel reduction is a procedure in where the proximal enamel of a tooth is reduced by mechanical methods. This procedure has gained popularity through the increase of clear aligner companies that plan this technique routinely [1]. Interproximal reduction was used by Ballard since 1944, and from there, several authors have described numerous protocols and indications [2]. It can be used for multiple objectives, as for reducing crowding, tooth size discrepancies, black triangles or just to reshape the anatomy of a tooth [3].

Tooth enamel has extraordinary structural and mechanical properties; however, once is lost, it cannot be regenerated [4-6]. Therefore, it is of outmost importance to try to preserve as much enamel as possible, to reduce the risk of caries or pulpal sensibility. Most authors agree that for this to happen, no more than 50% of the enamel should be trimmed [7-10]. However, for the clinician to find out the 50% of enamel thickness of each patient would only be possible with the use of a full mouth CBCT or full mouth digital periapical radiographs; however, the risk of radiation is far greater than the benefit [11,12]. The panoramic radiograph cannot be use for this purpose as it has been stated to have distortions of even 25% [13,14].

Therefore, it seems that the safest way on how to approach the decision on the amount of enamel to remove is by using average values. As a result, the primary objective of this study is to provide evidence about the average proximal enamel thickness from first molar to first molar in both arches; so that clinicians can have a reference of average values to plan interproximal enamel reduction with the least number of adverse effects as possible.

MATERIAL AND METHODS

This systematic review was conducted according to the guidelines of the Cochrane handbook for systematic review of interventions; furthermore, it abides by The Preferred Reporting Item for Systematic Review and Meta-Analysis (PRISMA) checklist reporting tool [15].

Registration

A protocol for this review was registered in PROSPERO's international prospective register of systematic reviews (crd.york.ac.uk/prospero) with the ID CRD42021244303.

Eligibility criteria

The PICO model was used to evaluate and select the in vitro and in vivo studies [16]. The population were permanent human maxillary and mandibular teeth. The intervention was the measurement of the proximal enamel thickness in studies both in vivo and in vitro. The comparison was the different thickness across both dental arches, and the outcome the total amount of thickness found with the calibrated tools. In vivo studies and in vitro studies that were eligible for inclusion in this systematic review, had the main characteristic that all teeth which were analyzed were in optimal conditions, with no signs of anomalies, wear, damage, or restorations; and instruments for measurement were calibrated.

Information sources and search strategy

An electronic search was employed within five major databases. Pubmed, Scopus, Medline (Ovid), Cochrane Library and Google Scholar were accessed between February 5 of 2021 and June 1st of 2021, to identify relevant research papers. Representative keywords included "enamel", "thickness", "orthodontics" "proximal thickness" and "quantification"; different combinations of these keywords with truncation, and medical subject headings (MESH) were used. There was no restriction regarding the date of publication of the studies, but only papers written in English were included.

Study selection

Study selection was carried in two phases based on the PICO strategy. In both phases the studies were evaluated by two review authors DAR and MACS. In the first phase, the titles and abstracts were screened from all the electronic databases and the unrelated studies were excluded. In the second phase full-text articles were

The Cohen's kappa coefficient was calculated to measure the interinvestigator agreement in the study selection process. In the case of disagreements, a third reviewer MFSO was involved to help reached a consensus after discussion.

Data collection process and data items

The same two authors conducted the data collection, and the disagreements between investigators were resolved until a consensus was reached, and in case it was necessary, the third person intermediated to help reach a decision. The data extraction included the following items: the year of publication, name of the authors, study design, sample size, location, intervention (how the measurement of the enamel thickness was performed), comparison (between the different teeth), and the outcome (total proximal enamel thickness with standard deviations). The reviewers were not blinded to the study title and authorship. Specific details can be found in the Table 1.

Risk of bias in individual studies

For the selected studies, the ROBINS-I tool was used to assess the risk of bias of non-randomized clinical studies [17]. There are no guidelines to assess the risk of bias of in vitro studies, therefore a modification of Cochrane risk of bias tool was implemented, as used in the study of Koletsi et al. [18]. The elements to evaluate were selection bias (experimental conditions), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting) and other bias. The quality of evidence and results were evaluated using The Joanna Briggs Institute (JBI) Critical Appraisal checklist tools for Quasi-Experimental Studies [19]. The risk of bias, as well as the quality, was assessed by the same two review authors.

Summary measures

The mesial and distal proximal enamel thickness of

Table 1. Description of the included studies.

Author, Year	Study design	Sample size / Location	Intervention	Comparison
Fernandes *et al*. 2011	In vitro	40 mandibular second bicuspids from a human teeth bank associated with a Public University located in Goiânia, Goiás, Brazil. Brazil.	Cut Sections. Enamel thickness was measured using millesimal precision equipment, the profilometer.	Crown width and proximal enamel thickness of mandibular second bicuspids.
Akli *et al.* 2020	In vitro	32 extracted permanent maxillary canines. Dental Clinics. USA.	Microcomputed tomography scanner. Measurements were made in MATLAB software.	Enamel thicknesses for the various maxillary canine surfaces
Veillini-Ferreira *et al*. 2012	In vitro	302 teeth. Brazil.	Cut Sections. Measurements of enamel thickness with a profilometer Profile Projector® PJ 300 with thousandth precision.	Proximal enamel thicknesses of human incisors, canines and premolars
Munhoz *et al*. 2012	In vitro	40 human maxillary first premolars were selected from two tooth banks. Brazil.	Cut Sections. Measurements in a profilometer.	Enamel thickness in maxillary first premolars.
Macha Ade C *et al*. 2010	In vitro	40 erupted sound human maxillary first bicuspids collected from white adult patients aged 19-31. Brazil.	Cut Sections. Digital images were acquired by a coupled camera and imported into the Image Pro-PlusTM software for taking tooth measurements.	Mesiodistal crown width and enamel thickness of maxillary first bicuspids.
Sarig *et al*. 2015	In vitro	109 teeth. White ethnicity. Range from 12 to 59 years. Department of Maxillofacial Surgery at Tel Aviv University in Israel. Israel.	Cut sections. Six measurements were made on each tooth with the Toolmakers microscope with a closed camera and a monitor at 10-times magnification.	To map the proximal enamel thickness of the complete maxillary and mandibular dentitions at the contact areas.

Hall *et al*. 2007.	In vivo	80 subjects (40 black and 40 white) at the Virginia Commonwealth University School of Dentistry. USA.	Digital periapical radiograph. Measurements from each radiograph using computer-aided design software precise to 0.001 mm.	Compare enamel thickness between black and white subjects, of mandibular incisors.
Harris et al. 1998	In vivo	115 American Caucasoids between the ages of 13 and 17 years. USA.	Periapical radiographs. Measurements were made with commercially available software (Adobe Photoshop).	Mesiodistal crown width, and proximal enamel thickness of the four maxillary permanent incisors.
Stroud *et al*. 1998	In vivo	59 and 39 Caucasian males and females, respectively. Range was 20 to 39 years. USA.	Rinn XCP bitewing instrument and a dental X-ray machine. A Bioquant computer system was used to manipulate the image, process the calculations, and correct the magnification.	Proximal enamel thickness of mandibular first and second premolars and molars.

Table 2. Comparative analysis of mean values in millimeters (mm) for the mesial and distal enamel thicknesses according to the studies.

Author	Central Incisor (mm)	Lateral Incisor (mm)	Canine (mm)	First Premolar (mm)	Second Premolar (mm)	First molar (mm)	Second molar (mm)
Fernandes *et al.* 2011	X	X	X	X	Md: RM: 1.40 (±0.17) RD: 1.46 (±0.12) LM: 1.35 (±0.22) LD: 1.44 (±0.21)	X	X
Hall *et al*. 2007.	Md: RM: 0.72 (±0.10) RD: 0.77 (±0.11) LM: 0.71 (±0.10) LD: 0.77 (±0.11)	Md: RM: 0.79 (±0.11) RD: 0.95 (±0.13) LM: 0.81 (±0.11) LD: 0.96 (±0.14)	X	X	X	X	X
Macha Ade C *et al.* 2010	X	X	X	Mx: RM: 1.08 (±0.14) RD: 1.29 (±0.12) LM: 1.19 (±0.25) LD: 1.29 (±0.18)	X	X	X
Vellini-Ferreira *et al*. 2012	Mx: M: 0.854 (±0.174) D: 1.015 (±0.173) Md: M: 0.675 (±0.144) D: 0.872 (±0.267)	Mx: M: 0.860 (±0.129) D: 1.002 (±0.176) Md: M: 0.734 (±0.139) D: 0.879 (±0.158)	Mx: M: 1.027 (±0.126) D:1.220 (±0.145) Md: M: 0.781 (±0.106) D: 1.014 (±0.118)	Mx: M: 1.220 (±0.173) D: 1.322 (±0.195) Md: M: 1.051 (±0.166) D: 1.266 (±0.187)	Mx: M: 1.101 (±0.176) D: 1.155 (±0.149) Md: M: 1.376 (±0.198) D: 1.450 (±0.172)	X	X
Munhoz *et al*. 2012	X	X	X	Mx: RM: 1.22 (±0.17) RD: 1.28 (±0.19). LM: 1.22 (±0.18) LD: 1.39 (±0.17)	X	X	X

Sarig *et al*. 2015	Mx: M: 0.81 (±0.06) D: 0.81 (±0.27) Md: M: 0.64 (±0.19) D: 0.60 (±0.18)	Mx: M: 0.76 (±0.14) D: 0.86 (±0.28) Md: M: 0.64 (±0.19) D: 0.60 (±0.18)	Mx: M: 1.10 (±0.21) D: 1.11 (±0.26). Md: M: 0.97 (±0.21) D: 1.30 (±0.61)	Mx: M: 1.13 (±0.15) D: 1.25 (±0.37) Md: M: 1.16 (±0.13) D: 1.05 (±0.24)	Mx: M: 1.41 (±0.27) D: 1.36 (±0.30). Md: M: 1.23 (±0.10) D: 1.30 (±0.20)	Mx: M: 1.35 (±0.29) D: 1.48 (±0.17) Md: M: 1.37 (±0.12) D: 1.40 (±0.20)	X
Harris *et al*. 1998	Mx: RM: 0.90 (±0.12) RD: 1.05 (±0.15) LM: 0.91 (±0.11) LD: 1.05 (±0.14)	Mx: RM: 0.91 (±0.12) RD: 1.01 (±0.12) LM: 0.91 (±0.11) LD: 1.02 (±0.14)	X	X	X	X	X
Akli *et al*. 2020	X	X	Mx: M: 0.856 (±0.183) D: 0.861 (±0.362)	X	X	X	X
Stroud *et al*. 1997	X	X	X	Md: M:0.99 (±0.21) D: 1.07 (±0.23).	Md: M: 1.19 (±0.21) D: 1.22 (±0.22)	Md: M: 1.28 (±0.23) D: 1.40 (±0.25)	Md: M 1.29 (±0.20) D: 1.48 (±0.26)

Mx: Maxilla, Md: Mandible, RM: Right quadrant mesial side, RD: Right quadrant distal side, LM: Left quadrant mesial side, LD: Left quadrant distal side, M: Mesial, D: Distal, ±: Standard Deviation, X: study didn't analyze that tooth.

maxillary and mandibular teeth were used as the outcome measured of this systematic review. In vitro and in vivo studies were selected for a broader sample; in vivo studies were measured by radiographic means, while in most of the in vitro studies the thickness was obtained by cut sections of the teeth, and the use of a profilometer and CBCT. The measurements were taken from the widest section of enamel at the mesial and distal sides, and values were reported individually according to the tooth evaluated in millimeters.

RESULTS

Study Selection

In this systematic review 3298 records were identified from the five electronic databases. Duplicates were removed manually, and 2128 studies were left. All the studies were screened based on the title and abstract. Afterwards, 67 studies were selected to be reviewed in depth; from those, 9 studies were selected to be included in the qualitative analysis as they fulfilled the eligibility criteria. The selection of articles was done in all stages by the two review authors. The interinvestigator agreement (Kappa) was calculated by evaluating selected titles and abstracts, with a value of 0.94, suggesting a high level of agreement between investigators. The search results are shown in the flow chart (Figure 1).

Study Characteristics

Nine studies in total were included. From the 9 studies, 6 were in vitro [20-25] and 3 in vivo [26-28]. The rationale of using both in vitro and in vivo studies was decided based on having the highest amount of high-quality data. In the in vitro studies, five [20-22,24,25] of them did the measurements based on cut sections of the teeth, while one [23] used a microcomputed tomography scanner. The 3 in vivo studies evaluated the enamel thickness from calibrated bitewings [28] and periapical radiographs [26,27]. No study had the same end goal, as each one decided which teeth to evaluate; nevertheless, all studies were made with the final goal of determining the enamel thickness for interproximal reduction.

Risk of bias assessment

There were 2 instruments used for the assessment of risk of bias, one for the in vitro, which was taken from a previous study as there are no instruments available for this type of studies (Table 3), and another one for the in vivo studies (Table 4). None of the analyzed studies were randomized, as a result instruments for non-randomized studies were implemented.

In all the in vitro studies, the detection bias had a high risk as the assessors were not blinded; additionally, there were other bias, as all authors assume the proximal contact was

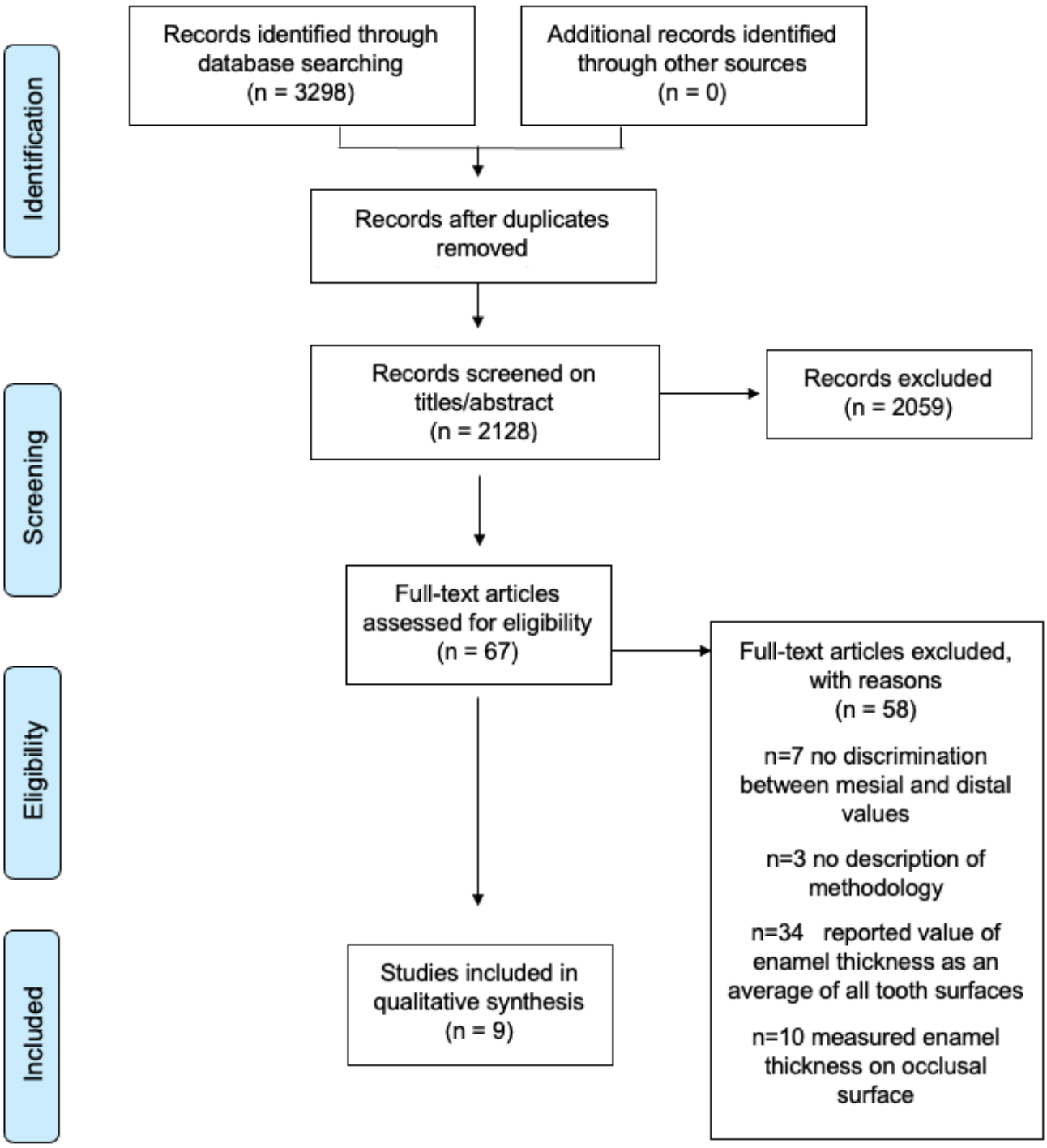

Figure 1. Flow chart according to the PRISMA Statement.

Table 3. Modification of Cochrane risk of bias tool.

	Selection bias	Detection bias	Attrition bias	Reporting bias	Other bias	Overall bias
Fernandes et al. 2011						
Akli et al. 2020						
Veillini-Ferreira et al. 2012						
Munhoz et al. 2012						
Macha Ade C et al. 2010						
Sarig et al. 2015						

Green: Low risk, Yellow: Moderate risk, Red: High risk

Table 4. ROBINS I: Risk of Bias of the included non-randomized studies (ROBINS-I tool).

	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall bias
Stroud et al. 1998								
Hall et al. 2007								
Harris et al. 1998								

Green: Low risk, Yellow: Moderate risk, Red: High risk.

the thicker part of the proximal enamel; however, this may not be entirely true, reason why these studies had a high risk of bias. The in vivo studies which were assessed with the Robins I Tool had a moderate risk of bias, having a moderate risk in the measurement of the outcome as there is no description if the assessors were blinded and additionally, there can be errors in measurements as the tools that were used to measure the distance were in 2 dimensions. Regarding quality, The Joanna Briggs Institute (JBI) Critical Appraisal checklist tools for Quasi-Experimental Studies was used (Table 5), in where all studies showed a high quality, except for the study of Harris et al, as they used photoshop to measure the enamel thickness.

Results of individual studies and synthesis of results

Differences between gender and ethnicity

From the selected studies, three authors [26-28] talked about the difference of proximal enamel thickness between genders, finding no difference between male and female subjects, even though male teeth were bigger than female. Between all studies, only Hall et al., examined the proximal enamel differences between two different racial ethnicities (African Americans and white subjects), in which they reported that the enamel thickness of African Americans was significantly thicker than in white subjects. Even though this study was focused on the width of incisors, the authors found that all enamel surfaces for black subjects were thicker than in white subjects with a P<.0001, compared to a P<.0005 for central and lateral incisors. For instance, the proximal enamel on the mesial and distal surface of the right central incisor in black subjects measured 0.76mm ± 0.39mm and 0.83mm ± 0.09mm respectively, compared to 0.67mm ± 0.09mm and 0.71mm ± 0.09mm for with subjects. Meanwhile, the right lateral in black subjects had a mesial proximal enamel thickness of 0.85mm ± 0.99mm and the distal side a value of 1.03mm ± 0.11mm, compared to 0.74mm ± 0.09mm and 0.87mm ± 0.11mm in white subjects, accordingly [26].

Differences between left and right side

There were four studies that evaluated the same teeth on the left and right side, and they were not able to find any significant difference between sides (20,21,24,25). For example, Munhoz LO *et al.* studied the maxillary first premolars, and the authors observed that the mean mesial enamel thickness of the maxillary right first premolars was 1.22mm, the same enamel thickness compared to the maxillary left first premolar. The relevance of this result is that the sample size comprised of 40 teeth, which adds reliability to the findings [24].

Differences between mesial and distal side

All studies agreed that the distal proximal enamel is thicker than the mesial. Veillini-Ferreira et al., observed that the distal proximal enamel was 0.1mm thicker compared to the mesial side [20], however, this value rose to 0.2mm in the mandibular canine and first premolar. Munhoz et al., and Harris et al. both observed something similar, with 0.1mm more enamel on the distal side compared to the mesial side [24, 27]; however, Carvalho et al. who studied the upper first premolars, saw that the distal proximal enamel was 0.2mm greater than the mesial side [25]. Another interesting result was observed by Stroud et al., who saw that the second mandibular premolars had 0.44mm more of proximal enamel thickness on the distal side compared to the mesial side [28]. Further information about the differences between the mesial and distal side can be found in the Table 2.

Recommendations in the included studies

Four out of the nine studies made recommendations regarding the amount of interproximal reduction that can be done in the patients. Veillini-Ferreira et al. suggested that 7mm of IPR (interproximal reduction) can be done safely in each arch [20], nevertheless, Sarig et al., mentioned that is possible to do 10.19mm and 9.78mm of IPR on the maxillary and mandibular arch, respectively [22].

Similarly, Stroud et al. reported that 9.8mm of IPR can be done in the mandibular arch, a value nearly the same as the mentioned by Sarig et al. On the other hand, Hall et al., did not gave an exact amount of IPR to be done in each arch, they only suggested to avoid performing more than 0.2mm of IPR in the mandibular incisors due to the values they found [28].

The mandibular central incisor was the tooth with the least amount of proximal enamel thickness [20], and it was seen by all studies that the further they moved distally the thicker the proximal enamel was therefore, less proximal enamel can be found towards anterior and more proximal enamel can be seen towards posterior.

Table 5. The Joanna Briggs Institute (JBI) Critical Appraisal checklist tools for Quasi-Experimental Studies.

	Clarity between cause and effect?	Similar study groups?	Similar treatment between participants?	Presence of a control group?	Multiple exposure of the outcome?	Follow up complete?	Outcomes of participants measured in the same way	Outcomes measured in a reliable way?	Appropriate statistical analysis used?
Harris et al. 1998	NA	Y	Y	N	Y	Y	Y	N	Y
Stroud et al. 1998	NA	Y	Y	N	Y	Y	Y	U	Y
Hall et al. 2007.	NA	Y	Y	N	Y	Y	Y	U	Y
Macha Ade C et al. 2010	NA	Y	Y	N	Y	Y	Y	Y	Y
Fernandes et al. 2011	NA	Y	Y	N	Y	Y	Y	Y	Y
Munhoz et al. 2012	NA	Y	Y	N	Y	Y	Y	Y	Y
Veillini-Ferreira et al. 2012	NA	Y	Y	N	Y	Y	Y	Y	Y
Sarig et al. 2015	NA	Y	Y	N	Y	Y	Y	Y	Y
Akli et al. 2020	NA	Y	Y	N	Y	Y	Y	Y	Y

DISCUSSION

One of the most used techniques in modern orthodontics is the interproximal reduction that has been popularized by many clear aligners' companies, which used IPR as a basic procedure for most of their treatments [29,30]. However, this raises a doubt about who is the one determining how much IPR must be done in the cases, and it makes professionals to worry about the safety of it, as not only orthodontist are the ones implementing this procedure, but clear aligners companies have made available this kind of treatment for general practitioners, and both the orthodontist and the general practitioner have different views on how much of IPR to perform and how to do it [31].

Interproximal reduction is not a new procedure and can be found in the literature of the last century, there are studies like the one of Dr. Arthur Leroy Hudsox, that was made in 1956 that made recommendations about the maximum amount of IPR that can be done in the lower anterior teeth. He recommended no more than 0.2mm of IPR on the lower centrals, no more than 0.25mm on the lower laterals, and a maximum of 0.3 on the lower canines [32]. Nevertheless, it raises another question about how clinicians are determining how much IPR can be done without generating adverse effects on their patients like pulpal injures, sensibility or bone loss due to closeness of the roots [33].

Clearly, the way on how the IPR is performed can affect the result, but it may be even more important the amount of enamel that is removed, as the enamel is a tissue that once is lost, it cannot be recovered [4,34]. It has been stated in the literature that 50% of the proximal enamel can be removed without harming the patient; nevertheless, the authors of this systematic review searched for the evidence regarding this claim, and this percentage doesn't come from randomized clinical trials; therefore, this information must be implemented carefully [35-37].

Additionally, if the value of 50% of the enamel is going to be used to determine the amount of IPR planned, then it is important to know the average values and the standard deviations of proximal enamel thickness, which was the main objective of this study (these values can be found in the (Table 2). Nonetheless, careful interpretation of this outcomes must be taken, as these values are the result of studies conducted in Brazil, United States of America, and Israel, so depending on the population in which the clinician is working, then adjustments might be needed.

One of the most interesting findings of this systematic review is that it shows that there is no significant difference between the proximal enamel thickness found in males and females.

Even though, males have larger teeth, it seems that the reason for this is a change in the amount of dentin and the size of the pulpal chamber as mentioned by Stroud et al., in 1994 [38]. As a result, there is no need to change the amount of maximum IPR due to the gender; however, there might be a need to change the amount depending on the ethnicity of the patient, but this can only be determined with more studies [39].

A key aspect to evaluate now that more adults are getting orthodontic treatment is the wear pattern. Brokos et al., studied the total proximal enamel thickness (mesial + distal) of the upper anterior teeth in 3 age groups (less than 30, between 31 to 50 and 51 or more), and what they saw was a difference of about 0.1mm between the lower age group and the older age group, a value that can be even greater on posterior teeth which are the ones that in most situations suffers the greatest amount of wear [40]. The studies included in this systematic review made their measurements in teeth without wear, as a result, if the clinician observes wear patterns, it might be appropriate to reduce the amount of IPR planned.

Strengths and limitation of the systematic review

No in vivo studies in where the measurement of the proximal enamel thickness was done with a CBCT were found. The in vivo clinical studies measured the proximal enamel width with periapical radiographs, which if not taken perpendicular to the tooth can provide misleading information about the enamel thickness, plus the distortion that is already present. Additionally, the interproximal enamel reduction is performed in the proximal contact of teeth; however, the in vitro studies assume the proximal contact was the thicker portion of the proximal enamel, something that in clinical scenarios might not be always the same.

A meta-analysis could not be performed due to the heterogenicity of the studies. However, a strength of this systematic review is that it included all the articles available in which the proximal enamel thickness was measured, and in which the value obtained was separated between mesial and distal sides including standard deviations.

Recommendations for future research

The future research should be focused in providing high quality evidence regarding the percentage of proximal enamel that can be removed without creating any harm, as the available information is based on case reports. Once these percentages are obtained, the outcomes reported in this systematic review can be mix with this percentages to determinate the average maximum of interproximal

reduction that can be perform. In addition, more in vivo studies are needed, in where the thickness of the proximal enamel is measured with more reliable sources as a CBCT from the real interproximal contact, and in addition, it might be helpful to make a distinction between age groups, as the number of adult patients being treated with orthodontics is increasing each day.

CONCLUSION

This systematic review exposes the average proximal enamel thickness for several ethnicities. This can be used as a guide to determine the amount of IPR that can be performed. Currently, it cannot be asserted the specific maximum amount for each tooth, as this will be determined by the percentage of enamel the clinician is comfortable in removing, which according to the literature should never be more than 50% of the total proximal enamel. Additionally, according to the findings, there is no need to differentiate between male or female when planning the amount of IPR; however, it is advisable to do the IPR towards the distal side, as the thickness is greater than in the mesial side.

CONFLICT OF INTEREST

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable

AVAILABILITY OF DATA AND MATERIALS

The data underlying this article are available in the article and in its online supplementary material.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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AUTHORS' CONTRIBUTIONS

Dr. David Arias Rivera oversaw the central idea, study design, selection of articles, execution of the work and writing of the systematic review. Dr. Miguel Angel Casillas Santana collaborated with the selection of the articles and with the revision of the systematic review format. Dr Marco Felipe Salas Orozco served as mediator between disagreements with the inclusion of articles between the two previously mentioned authors and with the revision of the final document.

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