

A clinical guideline for caries infiltration of proximal enamel lesions with resins

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Key points

Provide a critical appraisal of the scientific basis and the principles of the resin infiltration technique in proximal enamel lesions.

Assist dentists and, in general, professionals who deal with infiltration of proximal caries lesions.

Form guidelines that cover all aspects of the management of proximal enamel lesions upon resin infiltration.

Objectives The purpose of the present study is to establish a guideline on the management of proximal enamel lesions with resin infiltration. **Methods** Each article in compliance with the inclusion criteria was evaluated by two independent authors, individually. The methodological quality assessment of the selected articles was conducted using SIGN checklists. **Results** A total of 15 *in vivo* studies, 12 systematic reviews and one economic evaluation fulfilled the selection criteria for in-depth analysis of the full text and quality assessment. **Conclusions** Infiltration of incipient enamel caries lesions is a clinically feasible and effective method for the treatment of interproximal lesions with high success rates, taking also into consideration the limitations of this systematic review.

Introduction

In recent years a downward trend in caries, mainly in children and young adults, has been observed in most industrialised countries.¹ Nevertheless, dental caries, especially on proximal tooth surfaces constitutes a widespread health issue, with up to 50% of patients at the age of 21 years indicating carious or restored proximal surfaces.² The treatment of proximal early caries lesions remains a dilemma for modern dentistry, due to the massive loss of tooth structure on all restorative approaches, especially traditional restoration, which requires removal of the intact marginal ridge to gain access to the carious lesion beneath. Additionally, the early detection of proximal caries can be challenging.³ Studies point out the high importance of early stage prevention of the progress of caries, especially the formation of cavities, which is the typical development of the disease.⁴ Several approaches have been

proposed for the management of non-cavitated caries lesions, also known as white spot lesions, initial or early caries lesions. These approaches include remineralisation of the lesion with fluoride and casein phosphopeptide amorphous calcium phosphate, or usage of sealants.⁵ Minimal intervention dentistry research has explored a tissue preserving approach to arrest and control incipient lesions. Resin infiltration treatment can seal the micro porosities of incipient caries lesions and inhibit diffusion pathway to cariogenic agents, with the use of materials that were specifically developed for this treatment. Resin infiltrants are low-viscosity hydrophilic light-curing material, which are able to penetrate into the subsurface lesion, thus reducing microporosities, affording mechanical support and obstructing the acids hampering demineralisation. Resin infiltration treatment for proximal tooth surfaces, is consisted of the following stages: tooth surface cleaning; application of rubber dam; wedge fitting to gain sufficient separation of the teeth in order to be able to pass the application foil in the interdentium; surface etching for two minutes with HCL 15%; water-air spray in order to remove etching liquid for 30 seconds; application of 99% ethanol for 30 seconds to assist dryness and application of resin infiltrant which have

to be allowed to be set for three minutes, before being light cured for 40 seconds.⁶ While clinical research evidence on the technique is considerable, scientific literature lacks guidelines for the selection, the accurate application and the wider treatment plan. Most of the studies don't associate treatment application and follow up with ICDAS caries criteria, which constitute one of the most widespread caries detection and assessment systems.⁷ Thus, the purpose of the present study was to carry out, through a literature review, the scientific basis and the principles of the resin infiltration technique, in an effort to form guidelines that cover all aspects of the management of proximal enamel lesions upon resin infiltration.

Materials and methods

Outline for the guideline's method of development

The guidelines were developed by two university researchers/clinicians, who are certified as specialists in restorative dentistry. The clinicians selected the most frequent clinical questions encountered in treating proximal caries and used electronic databases to research and assess the best available scientific evidence for each question. A graded recommendation

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Table 1 Grading system for recommendations in evidence based guidelines

Levels of evidence	
1 ++	High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias
1 +	Well conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias
1 –	Meta-analyses, systematic reviews or RCTs, or RCTs with a high risk of bias
2 ++	High quality systematic reviews of case-control or cohort studies or High quality case-control or cohort studies with a very low risk of confounding, bias, or chance and a high probability that the relationship is causal
2 +	Well conducted case-control or cohort studies with a low risk of confounding bias or chance and a moderate probability that the relationship is causal
2 –	Case-control or cohort studies with a high risk of confounding bias or chance and a significant risk that the relationship is not causal
3tt	Non-analytic studies, for example, case reports, case series
4tt	Expert opinion
Grades of recommendations	
A	At least one meta-analysis, systematic review, or RCT rated as 1++ and directly applicable to the target population or a systematic review of RCTs or a body of evidence consisting principally of studies rated as 1+ directly applicable to the target population and demonstrating overall consistency of results
B	A body of evidence including studies rated as 2++ directly applicable to the target population and demonstrating overall consistency of results or extrapolated evidence from studies rated as 1++ or 1+
C	A body of evidence including studies rated as 2+ directly applicable to the target population and demonstrating overall consistency of results or extrapolated evidence from studies rated as 2++
D	Evidence level 3 or 4 or Extrapolated evidence from studies rated as 2+

was made for each clinical question (Table 1). The provisional guidelines were enhanced following discussion with university researchers and general practitioners.

Search strategy

A literature search was carried out through the Medline database (PubMed), the Cochrane Controlled Clinical Trials Register and Scopus. The search covered the period from January 1980 to March of 2017 and was undertaken by means of the following keywords: ‘proximal caries infiltration’, ‘resin infiltration incipient lesions’, ‘resin infiltration’ and ‘dental caries’.

Selection criteria

Articles selected for this study fulfilled the following criteria for inclusion: the title or abstract was relevant to the topic; reported a meta-analysis; randomised clinical trial (RCT), controlled clinical trial or a systematic review.

Data collection and analysis

Each article in compliance with the inclusion criteria was evaluated by two independent authors, individually, with regard to the quality of the study and particularly the generation of the randomisation sequence (allocation), the study design, the blind outcome assessment,

the control group and the follow-up completeness. No blinding to the authors was performed, during data extraction, while any inter-examiner conflicts were resolved by discussion. The same reviewers performed the quality assessment of the articles, with one author acting as the coordinator. The methodological quality assessment of the selected articles was conducted using SIGN checklists.⁸ Critical appraisal (i) of clinical trials was effected through the controlled trials checklist and (ii) of reviews the through the systematic reviews and meta-analyses checklist irrespectively.

Each selected article (clinical trials and reviews) was evaluated and the overall methodological quality of the study was rated. Criteria examined were as follows:

- For systematic reviews:
 1. The study addresses a clearly defined research question
 2. At least two people should select studies and extract data
 3. A comprehensive literature search is carried out
 4. Authors clearly state if or how they limited their review by publication type
 5. The included and excluded studies are listed

6. The characteristics of the included studies are provided
7. The scientific quality of the included studies is assessed and documented
8. The scientific quality of the included studies was assessed appropriately
9. Appropriate methods are used to combine the individual study findings
10. The likelihood of publication bias is assessed
11. Conflicts of interest are declared.

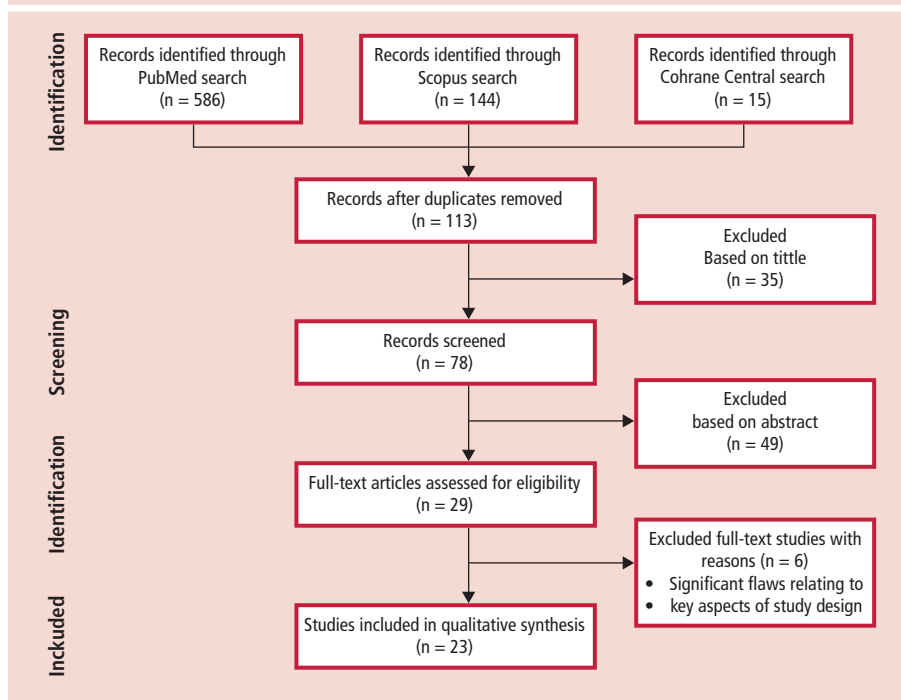
- For clinical trials:
 1. The study addresses an appropriate and clearly focused question
 2. The assignment of subjects to treatment groups is randomised
 3. An adequate concealment method is used
 4. Subjects and investigators are kept ‘blind’ about treatment allocation
 5. The treatment and control groups are similar at the start of the trial
 6. The only difference between groups is treatment under investigation
 7. All relevant outcomes are measured in a standard, valid and reliable way
 8. Investigation of the percentage of individuals or clusters recruited into each treatment arm of the study who dropped out before the study was completed
 9. All the subjects are analysed in the groups to which they were randomly allocated
 10. Where the study is carried out at more than one site, results are comparable for all sites.
- The quality of the studies was classified as:
 - High quality: majority of criteria met. Little or no risk of bias
 - Acceptable: most criteria met. Some flaws in the study with an associated risk of bias
 - Low quality: either most criteria were not met, or significant flaws existed relevant to key aspects of the design of the study
 - Reject: either most criteria were not met or significant flaws relating to key aspects of the design of the study. Conclusions are likely to change, in light of further studies.

Results

Study selection

Our initial searches on PubMed, Cochrane Controlled Clinical Trials Register and Scopus yielded 78 articles. Following initial application of the exclusion criteria and removal of duplicates, based on title and abstract screening,

Fig. 1 Research flow diagram



a total of 17 *in vivo* studies, six systematic reviews and one economic evaluation fulfilled the selection criteria of the present study; said material was selected for in-depth analysis and quality assessment. The selection process is reported in Figure 1.

Study characteristics

A summary of the data items collected for each study included in the study, along with quality assessment results, is given in (Table 2). Selected studies were published between 2005 and 2018. The majority of the studies (65%) were rated to be acceptable, meeting most criteria; even though they contained flaws and/or an associated risk of bias, including outcome assessments that were not blinded, poor methods of randomisation or randomisation and allocation concealment not being stated, or no extensive data reports being available. Twenty-six percent of the studies were rated of high quality, three studies were rated of low quality, and three were rejected following the quality assessment due to significant flaws relevant to key aspects of the design of the study.

Discussion

To the best of our knowledge, this is the first attempt to formulate clinical guidelines on the infiltration of proximal enamel tooth surfaces with resin. The present guidelines take into consideration the patient's potential to improve

or maintain his/her quality of life and include recommendations of all ages. For the purpose of its development, key clinical questions were examined, namely with regard to the resin infiltration's ability to arrest proximal caries lesions.

CQ1: Does resin infiltration have the ability to arrest proximal caries lesions?

Resin infiltration is capable of hampering or arresting proximal caries lesions¹² (grade of recommendation A). The careful selection and supervision of the case is crucial. Within the follow-up interval of 12 to four years, resin infiltration leads to high efficacy in reducing or hampering the progression of non-cavitated proximal caries (grade of recommendation A).^{9,10,12,13} A period between six to 12 months seems adequate for the supervision of the lesion and for retreatment, should such a course of action prove necessary (grade of recommendation A). Nevertheless, research with an extended observation time is warranted to form a follow up protocol.

CQ2: Does resin infiltration belong to preventive or invasive treatments?

Resin infiltration is an invasive treatment which stands between non-invasive (for example, fluoride) and more invasive (for example, restoration) approaches. Resin infiltration is a micro-invasive technique, as in the process a superficial layer of less than 30 µm of

demineralised and sound enamel is removed (grade of recommendation A).^{11,12-15} The infiltration treatment can significantly postpone the first invasive intervention, averting the circle of treatment and re-treatment that would follow, and thus being especially advantageous in proximal surfaces, where a relatively large ratio of healthy hard tissue must be removed.

CQ3: When is a case suitable for treatment with resin infiltration technique?

Lesions that indicate radiographically, radiolucency in the inner half of the enamel (E2), and radiolucency, in the outer third of the dentin (D1), are suitable for resin infiltration treatment. These lesions would be active, presenting no signs of cavitation (grade of recommendation A).^{10-12,13-17,18-20} Studies with fewer methodological limitations as per ICDAS-Scores should be performed in order to create a high-level guide for predictable and effective clinical decisions.

CQ4: Is resin infiltration successful, regardless of the degree of caries risk?

There is no evidence that resin infiltration can inhibit the progression of lesions in patients who are at high risk of dental caries; success rate is lower and observation must be more frequent (grade of recommendation D).^{17,19,20} Further research is warranted to support the issue posed with the question.

CQ5: Is resin infiltration appropriate for children?

Resin infiltration technique is well accepted by children and young adults (grade of recommendation A). However, the simplest interventions for approximal initial caries lesions promote less discomfort and should be preferred when possible. Resin infiltration is suitable for treatment of primary teeth with initial approximal caries (grade of recommendation A).²⁰⁻²⁴ It must be investigated whether the application protocol for primary and permanent teeth should be different, based on the different characteristics of their structures.

CQ6: How long does resin infiltration treatment for a proximal caries lesion take?

Twenty-four minutes is a normal application time for clinicians without prior experience on their first infiltrations. Infiltration treatment is well accepted by patients. The location, and

Table 2 A summary of the data items collected for each study included in the study along with quality assessment results (cont. on page 303)

First author (Reference No.)	Pub. year	Study design	Sample (Drop out)	Type of enamel	Material	Evaluation methods	Follow up	Quality score	Key outcomes
Tellez M ¹⁰	2013	Review	–	–	Adhesive, sealant icon	–	–	(++) High quality	Sealants and resin infiltration studies point to a potential benefit in slowing the progression or reversing non cavitated carious lesions
Ekstrand KR ¹¹	2010	CT	48 (6)	Primary molar	Icon, SDF	Radiographs clinical assessment	12 months	(+) Acceptable	Resin infiltration was superior to fluoride varnish treatment only in reducing caries progression.
Kielbassa AM ²¹	2010	Review	–	–	Adhesive, sealant icon	–	–	(+) Acceptable	Resin infiltration is a very promising micro invasive approach to preserve dental hard tissues
Caglar ¹³	2015	CT	21	Permanent incisor, premolar	Icon	Radiographs, discoloration & marginal adaptation tests	4 years	(+) Acceptable	Proximal infiltration is an effective prophylactic measure in adolescents
Altarabulsi MB ¹⁴	2014	CT	47 (45)	Primary molar Permanent molar, premolar, incisor	Icon	Radiographs clinical assessment	12 months	(+) Acceptable	Infiltration showed no clinical problems and very good results regarding the clinical quality and safety
Kielbassa AM ¹⁵	2009	Review	–	–	Icon	–	–	(+) Acceptable	Infiltration closing the gap between oral hygiene and minimally invasive dentistry.
Paris S ¹⁶	2010	RCT	22 (0)	Permanent teeth	Icon	Radiographs clinical assessment	18 months	(++) High quality	Within the follow-up interval of 18 months, caries infiltration reduces lesion progression of non-cavitated interproximal caries lesions
Borges BC ¹⁷	2011	Review	–	–	Icon	–	–	(-) Low quality	Non-surgical treatments should be preferred, in order to increase the tooth's longevity in the mouth
Martignon S ¹⁸	2012	RCT	39 (2)	Permanent molar, premolar	Sealant icon	Radiographs clinical assessment	36 months	(++) High quality	After three years, the higher efficacy shown by pair-wise radiographic readings for the infiltration, and for the sealing in comparison with a placebo
Kantovitz KR ¹⁹	2010	Review	–	–	Sealant Icon	–	–	(++) High quality	Further well-designed in vitro and in vivo studies should be performed to provide high-level evidence guide the best clinical decision
Ekstrand K ²⁰	2012	Review	–	–	Sealant icon	–	–	(-) Low quality	Most of literature clinical trials performed by specialists under very controlled conditions and are of relatively short duration
Senestraro SV ²¹	2013	RCT	30 (10)	Permanent teeth	Icon	Photographs clinical assessment	18 months	(+) Acceptable	Infiltration significantly reduced the size of white spot lesions
Peters MC ²²	2014	RCT	10 (4)	Permanent teeth	Icon	Radiographs clinical assessment	36 months	(+) Acceptable	Infiltration continued to stabilise early non-cavitated lesions in a small population with extremely high caries-activity.
Rossiza J ²³	2014	CT	18	Permanent teeth	Icon	Radiographs clinical assessment	12 months	(+) Acceptable	Further research is required to proof the hypothesis that infiltration is equally successful nevertheless the degree of caries risk
Mattos-Silveira J ²⁴	2014	RCT	141 (0)	Primary molar	Icon SDF	Children's discomfort (Wong-Baker faces scale)	–	(+) Acceptable	Infiltration has been well accepted by young adults. The simplest interventions for approximal initial caries lesions should be preferred
Ammari ²⁵	2017	RCT	50 (8)	Primary molar	Icon	Radiographs clinical assessment	12 months	(++) High quality	Within the follow-up interval of 12 months, 5 (11.9%) test lesions and 14 (33.3%) control lesions progressed

Table 2 A summary of the data items collected for each study included in the study along with quality assessment results (cont. from page 302)

First author (Reference no.)	Pub. year	Study design	Sample (Drop out)	Type of enamel	Material	Evaluation methods	Follow up	Quality score	Key outcomes
Gateva N ²⁶	2012	CT	26 (6)	Primary teeth	Icon	Radiographs clinical assessment	12 months	(+) Acceptable	Infiltration is less suitable for primary teeth with initial approximal caries in high risk children. Further research about protocol for primary teeth is required
Martignon S ²⁷	2010	RCT	91 (35)	Primary first molar	Sealant	Radiographs clinical assessment	30 months	(++) High quality	Sealing proximal lesions should be restricted to children considered to be at high risk of lesion progression
Altarabulsi MB ²⁸	2013	CT	50 (0)	Primary teeth, Permanent teeth	Icon	Questionnaires clinical assessment	–	(+) Acceptable	A mean application time of 24 minutes for clinicians without prior experience seems a reasonable time frame
Soviero VM ²⁹	2013	CT	59 (48)	Primary molar	Icon	Polarized light microscopy SEM analysis	–	(+) Acceptable	Longer application times did not result in significantly deeper or more complete penetration
Schwendicke F ³⁰	2014	Economic evaluation	50	Posterior teeth	Icon	Cost/ effectiveness analyses	–	(++) High quality	Infiltration treatment is more effective, but usually more costly than noninvasive therapy
Martignon S ³¹	2006	RCT	82 (10)	Permanent molar, premolar	Sealant	Radiographs clinical assessment	18 months	(+) Acceptable	Sealing proximal lesions provided a feasible technique and should be used when other preventive methods do not work
Gomez S ³²	2005	RCT	50	Permanent molar, premolar	Sealant SDF	Radiographs clinical assessment	24 months	(+) Acceptable	Sealant has the potential to act as a noninvasive treatment for early approximal enamel lesions
Gomez S ³³	2005	RCT	7 (0)	Permanent premolar	Sealant	SEM analysis	–	(+) Acceptable	Use of a bonding system prior to application doesn't increase the resin penetration length under non-contaminated conditions

separation problems, as well as the experience of the clinician are important factors that can influence the duration of the treatment (grade of recommendation B).²⁴

CQ7: Can a clinician without prior experience perform resin infiltration?

A dentist without special training is able to apply resin infiltration. However, experience helps reduce application time.^{24,25} There isn't much evidence that supports this clinical question (grade of recommendation B); however, we recommend training to understand the philosophy (indication, requirements, need of monitoring) and the pitfalls of the technique.

CQ8: Is longer infiltrant application time beneficial for deeper resin penetration?

Application time longer than 120 seconds in primary teeth does not result in significantly deeper or more complete penetration. There isn't evidence that deeper penetration is necessary for a better treatment outcome. Porosity volume is critical, considering active lesions are certainly easier to infiltrate.²⁶ This question was addressed based on *ex/in vivo* studies.

CQ8: Should fluoridation regimen be continued?

We came across no evidence to support that fluoridation is useful for an infiltrated lesion. Fluoridation treatment must be continued, of course, for the rest of dentition and could increase the possibility of lesion hampering; one should consider that proximal surfaces are less accessible for patients and that mineral islands on the surface of the lesion could be the onset for further demineralisation of infiltrated areas at the bottom of the lesion.^{16,20,25}

CQ9: Is resin infiltration a cost effective therapy?

Cost effectiveness varies based on the tooth and surface level (grade of recommendation B). In ICDAS-2 lesions non-invasive therapy is the least costly strategy, followed by resin infiltration. In ICDAS-3 lesions micro invasive therapy is the least costly strategy, followed by non-invasive and invasive treatment. Cost and effectiveness parameters may vary, depending on the tooth and the surface level.³⁰ However, this study was a computer simulation in accordance to the settings of the German healthcare system so results could vary in different countries.

CQ10: Can resin infiltrants be combined with conventional resin restorations?

Resin infiltrants can be combined with conventional resin restorations in cases of more complex treatments (grade of recommendation B).^{9,11} More research is warranted to conclude whether resin infiltration is advantageous, taking into consideration the adhesive performance between resin infiltrants, composite resins and resin cements.

CQ11: Can a lesion be re-infiltrated?

There is no evidence to support that re-infiltration is effective. Re-infiltration is possible if necessary.⁹ Prior to re-infiltration, the reason of failure must be investigated, as well as the patient's requirements.

CQ12: In cases where resin infiltration is not thorough, could it prove disadvantageous to caries lesion progression?

Caries progression could be facilitated in cases where the lesion is not properly infiltrated. Thickness of the eroded etched surface becomes significantly reduced after

HCL etching, in comparison to the thickness achieved with phosphoric-acid etching. As a result, this surface is prone to a new acid attack (grade of recommendation A).¹⁵

CQ13: Could we make use of dental adhesive instead of low viscosity resin infiltrant?

Adhesives could be used for proximal lesion sealing (grade of recommendation B).^{28,29} Adhesives were the first materials used for caries lesion infiltration. Under clinical uncontaminated conditions, usage of a bonding agent prior to the application of resin infiltration or resin sealant did not increase the resin penetration depth. Additionally, dental adhesive application requires two visits, considering, in these sealing studies, temporary tooth separation was used.^{23,28,29}

CQ14: What properties must resin infiltration materials have? Do resin infiltration and sealing have a substantial difference?

Resin infiltration has higher efficacy and constitutes a one-visit approach.^{31–33} The resin infiltration creates a barrier inside the lesion by replacing the mineral lost, while sealing creates a barrier on the top of the lesion surface. Infiltrants should be low viscosity monomers, in order to infiltrate the caries lesion in depth, while simultaneously be able to form a thick film in order to resist degradation outside the lesion. For deeper infiltration lower viscosity infiltrants could be used, but the viscosity of the monomer is inversely proportional to the oxygen inhibition of polymerising monomers.¹⁶ New resin infiltrants must be tested with fillers that remain in the surface, increasing its properties and allowing the residual resin to infiltrate the deeper layers of the lesion; this synthesis seems to be ideal for the infiltration technique.

Conclusions

The goal of these guidelines is to assist dentists and, in general, professionals who deal with infiltration of proximal caries lesions. The guidelines, thus, offer a foundation of recommendations and guidance for making decisions and treatment. Yet, it cannot be a substitute for the judgment of experienced

professionals in the actual clinical situation. Taking into consideration that a meta-analysis was not performed (provided the limitations of this systematic review) infiltration of non-cavitated enamel caries lesions is a clinically feasible and effective method for the treatment of interproximal lesions with high success rates. The right management of the cases and the accurate application technique, in combination with a substantial caries remineralisation protocol, constitutes a controlled ultraconservative restorative approach for proximal caries lesions. Due to the small observation time of the contributing studies and their methodological limitations, future research should emphasise the efficacy of resin infiltration in patients with high risk of dental caries, providing a framework for combination with conventional adhesive restorations and trial of new improved infiltration materials.

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