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RESIN INFILTRATION WITH ICON AS A TREATMENT FOR DEVELOPMENTAL ENAMEL DEFECTS: MOLAR–INCISOR HYPOMINERALIZATION AND DENTAL FLUOROSIS

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ABSTRACT

Molar–incisor hypomineralization (MIH) and dental fluorosis are developmental enamel defects that compromise dental aesthetics and negatively affect patients' quality of life. Resin infiltration using the Icon system has emerged as a minimally invasive treatment option for these conditions. This review aimed to evaluate the effectiveness of Icon resin infiltration in the management of MIH and dental fluorosis based on the available scientific literature. A literature review was conducted using the PubMed and Google Scholar databases to identify studies investigating the use of resin infiltration for the treatment of MIH and dental fluorosis. The available evidence indicates that Icon resin infiltration effectively improves dental aesthetics, reduces the visibility of enamel opacities, and decreases hypersensitivity in patients with MIH. In the management of dental fluorosis, resin infiltration has demonstrated greater efficacy than microabrasion or bleaching alone, while the most favorable aesthetic outcomes have been achieved when resin infiltration is combined with tooth bleaching. Icon resin infiltration is a safe and effective minimally invasive treatment for MIH and dental fluorosis, particularly in cases presenting with mild to moderate enamel defects. Nevertheless, further well-designed clinical studies with long-term follow-up are required to confirm the durability and long-term effectiveness of this treatment approach.

KEYWORDS

MIH, Dental Fluorosis, Resin Infiltration, Icon, Developmental Enamel Defects

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Introduction

Developmental enamel defects represent structural abnormalities of enamel that constitute important aesthetic, functional, and psychological challenges frequently encountered in clinical dental practice [1]. The altered appearance of enamel results from disturbances in amelogenesis occurring during tooth development. These disturbances may lead to either quantitative or qualitative defects of enamel. The timing of ameloblast activity, together with the duration and severity of the developmental insult, may cause temporary or permanent dysfunction of these cells, ultimately resulting in alterations in tooth color and morphology [2]. Clinically, developmental enamel defects manifest as enamel discoloration, aesthetic impairment, dentin hypersensitivity, and increased susceptibility to dental caries and erosive tooth wear [3]. Beyond their clinical manifestations, these defects substantially affect patients' daily lives. Individuals commonly report discomfort associated with dentin hypersensitivity and impaired oral function, while visible enamel defects adversely influence self-esteem and social interactions [4]. Adolescents with noticeable enamel discolorations frequently avoid smiling, limit social engagement, and experience reduced self-confidence because of the aesthetic appearance of their teeth [5]. Oral health-related quality of life (OHRQoL) encompasses four principal domains: orofacial appearance, orofacial pain, oral function, and psychosocial well-being [6]. In contemporary dentistry, the aesthetic outcome of treatment is considered equally important as pain relief and restoration of normal stomatognathic function, reflecting the growing importance of psychosocial well-being and patients' self-perception [7].

Microabrasion is a minimally invasive technique used to treat superficial white enamel opacities. The procedure involves controlled removal of the superficial demineralized enamel layer using a mixture of hydrochloric acid and a silica-containing abrasive paste applied with a rubber polishing cup. However, in extensive lesions, microabrasion may result in excessive loss of demineralized enamel. Restorative approaches employing composite resin or ceramic materials can provide excellent aesthetic outcomes but inevitably require irreversible removal of sound dental hard tissues. Consequently, minimally invasive treatment strategies are preferred whenever possible, as they preserve healthy tooth structure and reduce the likelihood of future restorative interventions [8,9].

A major advantage of resin infiltration for the treatment of enamel discolorations is that it achieves therapeutic and aesthetic improvement without removing healthy dental hard tissues or requiring local anesthesia [10]. Furthermore, resin infiltration can be combined with other minimally invasive techniques, including tooth bleaching and microabrasion, to enhance aesthetic outcomes while preserving intact enamel [11]. Conventional restorative treatment of carious lesions relies on external sealing achieved by adhesion between restorative materials and tooth tissues. In contrast, resin infiltration penetrates into the microporosities of demineralized enamel. Arrest of lesion progression is achieved by occluding the porous network within the lesion itself, thereby preventing further diffusion of acids into the enamel [12]. This process stabilizes the lesion and creates a diffusion barrier that inhibits acid penetration from the oral environment [13]. Although initially developed for the treatment of non-cavitated carious lesions, resin infiltration has also been successfully applied to other conditions characterized by increased enamel porosity, including molar–incisor hypomineralization (MIH), dental fluorosis, and idiopathic white spot lesions [12]. In addition to its therapeutic effect, resin infiltration provides significant aesthetic improvement. Filling the porous enamel with a low-viscosity resin modifies its refractive index, reducing light scattering and effectively masking white enamel opacities. This optical phenomenon has proven beneficial not only for caries-related white spot lesions but also for developmental enamel defects such as MIH and dental fluorosis [14]. Successful resin infiltration requires careful preparation of the enamel surface. Initially, a 15% hydrochloric acid gel (Icon Etch) is rubbed onto the lesion for approximately two minutes to remove the hypermineralized superficial layer. Subsequently, 99% ethanol (Icon Dry) is applied to desiccate the moist demineralized enamel matrix and facilitate penetration of the hydrophobic infiltrant into the porous lesion body. Depending on the clinical situation, the etching procedure may be repeated until the lesion becomes optically less visible following ethanol application, indicating adequate surface preparation. A layer of low-viscosity triethylene glycol dimethacrylate (TEGDMA)-based resin infiltrant (Icon Resin) is then applied and allowed to penetrate the lesion for at least three minutes while protecting the tooth from ambient light to prevent premature polymerization. Excess material is removed with a cotton pellet before light curing. A second layer of infiltrant is subsequently applied to compensate for polymerization shrinkage, followed by final light curing and polishing of the tooth surface [13].

The aim of this review was to characterize the treatment protocols and clinical effectiveness of Icon resin infiltration in the management of two major developmental enamel defects—molar–incisor hypomineralization (MIH) and dental fluorosis—with particular emphasis on therapeutic outcomes, aesthetic improvement, and the psychological impact of treatment on affected patients.

Materials and Methods

Relevant scientific publications were identified through a systematic literature search conducted in the PubMed and Google Scholar databases. The literature search included the following keywords: developmental enamel defects, enamel demineralization, molar–incisor hypomineralization (MIH), dental fluorosis, resin infiltration, Icon, and oral health-related quality of life (OHRQoL). Only articles published in English were included in the review. Publications in other languages were excluded. The literature search and study selection were performed between May and July 2026.

Molar–Incisor Hypomineralization (MIH)

The term molar–incisor hypomineralization (MIH) was introduced by Weerheijm et al. to describe qualitative enamel defects affecting one or more permanent first molars, frequently accompanied by involvement of the permanent incisors [15]. The etiology of MIH is considered multifactorial. Various prenatal, perinatal, and postnatal factors may interfere with amelogenesis during critical stages of enamel development. Proposed etiological factors include episodes of childhood fever, systemic infections, childhood illnesses, medications administered during pregnancy or early childhood, exposure to environmental toxins, and complications occurring during pregnancy or delivery [16]. Clinically, MIH is characterized by porous enamel opacities ranging in color from white-creamy to yellow or brown. These lesions result from disturbances in both the mineral and protein composition of enamel [17]. Compared with healthy enamel, hypomineralized enamel exhibits reduced mineral content, an altered calcium-to-phosphorus ratio, increased carbonate concentration, poorer crystal organization, and increased porosity. Consequently, MIH-affected enamel demonstrates significantly lower mechanical properties, including reduced hardness and elastic modulus, making it more susceptible to post-eruptive enamel breakdown [18].

Three degrees of MIH severity have been described and are presented in Table 1:

Table 1. MIH Classification and Characteristics [19]

Stage of MIH	Description of tooth enamel	Hipersensitivity
Mild	Well-demarcated white or cream opacities affecting non–occlusal stress-bearing surfaces. In incisors, these lesions are usually limited to no more than one-third of the clinical crown and present as opaque areas.	No
Moderate	Defects affect one or two surfaces of the molar without cusp involvement. Well-demarcated opacities may be observed in both molars and incisors. In incisors, aesthetic defects typically involve one-third to two-thirds of the clinical crown and appear as white or cream opacities.	Yes
Severe	Post-eruptive enamel breakdown accompanied by extensive loss of molar crown structure. Carious lesions extend to the cusps. Incisors present with severe aesthetic defects characterized by well-demarcated yellow to yellow-brown opacities involving up to two-thirds of the clinical crown.	Yes

According to Schwendicke et al., the global prevalence of MIH is approximately 13.1%, affecting an estimated 878 million individuals worldwide, with approximately 17.5 million new cases diagnosed annually. Among affected individuals, 27.4% require treatment for pain and dentin hypersensitivity [20]. Patients with MIH frequently experience symptoms that negatively affect their oral health-related quality of life. Teeth affected by MIH are highly sensitive to thermal and mechanical stimuli owing to dentin exposure and hydrodynamic movement of dentinal fluid induced by temperature changes, mechanical manipulation, tactile stimulation, or osmotic alterations [21]. Moreover, achieving profound local anesthesia in teeth affected by MIH is often clinically challenging, complicating restorative treatment [22]. The severity of clinical manifestations is closely related to lesion color. Yellow and brown opacities generally indicate more severe hypomineralization and are associated with an increased risk of post-eruptive enamel fracture, restorative treatment failure, and the need for more extensive restorative procedures compared with white lesions [23]. Children with MIH frequently experience impaired oral health-related quality of life. Visible enamel defects, dentin hypersensitivity, occasional halitosis, and pain during the consumption of cold or acidic foods negatively affect everyday functioning [24]. In addition, affected children often report lower self-esteem, compare their appearance with that of their peers, and may become self-conscious about the appearance of

their teeth. Negative comments from peers can contribute to social isolation, emotional distress, and diminished quality of life [25].

The management of MIH depends on lesion severity and the patient's clinical needs. Preventive strategies, including the application of fluoride varnishes and casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) preparations, have demonstrated favorable outcomes in promoting remineralization of affected enamel, reducing caries susceptibility, and alleviating dentin hypersensitivity [26]. Long-term restorative treatment using resin composite materials is less predictable because severely hypomineralized enamel exhibits reduced bonding strength to adhesive systems. Consequently, composite restorations placed in MIH-affected teeth may show reduced longevity and an increased risk of marginal failure and secondary caries [27]. For extensive defects involving permanent first molars, full-coverage restorations such as stainless steel crowns, lithium disilicate crowns, or zirconia crowns are recommended. Current evidence suggests that all three restorative approaches provide satisfactory long-term clinical outcomes [28].

For anterior teeth, where aesthetics is the primary concern, Icon resin infiltration represents an effective minimally invasive treatment option. In a 2026 study, Casaña-Ruiz, Vello-Ribes, and Catalá-Pizarro [14] demonstrated that Icon resin infiltration significantly improved the color characteristics of MIH lesions, as assessed using the CIELAB color system. The treatment resulted in a significant reduction in lesion size and visibility, although its effectiveness depended largely on the initial color of the enamel opacity. White opacities responded significantly better than yellow or brown lesions. In addition to the aesthetic improvement, patients also experienced a reduction in hypersensitivity affecting the anterior teeth.

Similarly, Brescia et al. (2022) [29] evaluated resin infiltration in 33 patients involving 114 teeth affected by MIH. Before treatment, all lesions were considered clinically unsatisfactory. Following the Icon procedure, aesthetic improvement was observed in every patient. Clinical outcomes were rated as excellent in 60.6% of treated teeth, whereas 15.1% of cases remained clinically unsatisfactory. Two-year follow-up demonstrated excellent color stability, and in some cases the visible size of the enamel opacities decreased further over time. Importantly, even patients whose clinical outcomes were judged as suboptimal by investigators reported satisfaction with treatment because of the reduced visibility of enamel defects and decreased dentin hypersensitivity.

Altan and Yilmaz (2023) [30] assessed the effectiveness of Icon resin infiltration in permanent anterior teeth affected by MIH using laser fluorescence (DIAGNOdent Pen), spectrophotometry, and cross-polarized photography. Their study included 116 permanent maxillary central incisors from 37 patients. Measurements obtained immediately after treatment demonstrated significant improvement in enamel appearance according to both laser fluorescence and polarized photographic analysis. At the six-month follow-up examination, only minimal changes were observed, indicating excellent clinical stability of the treatment outcomes. The authors concluded that Icon resin infiltration is an effective minimally invasive treatment for anterior MIH lesions.

However, treatment success varies according to lesion characteristics. White opacities generally exhibit greater color improvement and blend more effectively with the surrounding healthy enamel than yellow or brown lesions. Although aesthetic improvement can also be achieved in darker lesions, the outcomes are less predictable because these lesions typically represent deeper enamel hypomineralization with greater porosity and structural disorganization, limiting complete penetration of the infiltrating resin [31].

Dental Fluorosis

Dental fluorosis is a developmental enamel defect caused by excessive fluoride exposure during tooth development. The period of greatest susceptibility to fluorosis occurs between 20 and 30 months of age. The recommended maximum daily fluoride intake is 0.05–0.07 mg F/kg body weight; exceeding this level may result in dental fluorosis. The condition is characterized by hypomineralized enamel with increased porosity, which clinically manifests as white enamel opacities [32].

Dental fluorosis presents with a broad spectrum of clinical manifestations. Enamel discolorations may appear white, yellow, or brown. The enamel surface may remain smooth or exhibit pitting defects of varying severity. In more advanced cases, lesions may present as horizontal bands extending across the entire tooth surface and, in severe forms, may involve the underlying dentin [33]. The severity of dental fluorosis depends on several factors, including the age at which excessive fluoride exposure occurs, the duration of exposure, body weight, physical activity, and skeletal growth [34].

The Dean Index classifies dental fluorosis into five levels of severity:

Table 2. Fluorosis Classification based on Dean's Index [35]

Dean's Index	Description of tooth enamel
Normal	Smooth, glossy, pale creamy-white translucent surface
Questionable	A few white flecks or white spots that cannot be determined as very mild or normal.
Very mild	Small, opaque, paper-white areas covering less than 25% of the tooth surface. This also includes teeth showing no more than about 1–2 mm of white opacity at the tips of the summits of the cusps of the bicuspids or second molars.
Mild	Opaque white areas covering less than 50% of the tooth surface.
Moderate	All tooth surfaces affected; marked wear on biting surfaces; brown stains may be present.
Severe	All tooth surfaces affected; discrete or confluent pitting; brown stains present.

The enamel alterations associated with dental fluorosis often result in an unaesthetic appearance that differs from the dental appearance generally perceived as normal among peers. Consequently, affected individuals, particularly adolescents, may feel self-conscious and socially disadvantaged because of the visible discoloration of their teeth during smiling, which may negatively affect self-esteem and self-confidence [36].

Several treatment options are available for teeth affected by dental fluorosis. When structural destruction involves extensive portions of the clinical crown, particularly the occlusal surfaces, restorative treatment with porcelain veneers or full-coverage crowns may be indicated. However, these approaches are invasive and require irreversible removal of healthy dental hard tissues [37]. Therefore, whenever possible, minimally invasive treatment modalities should be preferred.

Preventive treatment using fluoride varnishes or casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) preparations may reduce the risk of dental caries and promote remineralization of hypomineralized enamel. Nevertheless, these therapies are generally insufficient to eliminate the unaesthetic white enamel opacities associated with fluorosis [38,39].

In a clinical study published in 2023, Asthana, Patel, and Parma [40] compared enamel microabrasion and Icon resin infiltration for the treatment of fluorosis-related enamel defects. Sixty-six teeth were allocated equally into two treatment groups. Both treatment modalities significantly reduced the visibility of white enamel opacities; however, the aesthetic improvement was considerably greater in the resin infiltration group. Furthermore, color stability assessed at one- and three-month follow-up examinations was superior following Icon resin infiltration. The authors concluded that although both techniques were effective in treating fluorosis-related enamel lesions, resin infiltration provided significantly better aesthetic outcomes.

A meta-analysis by Bourouni et al. (2021) [41] demonstrated that treatment with the low-viscosity Icon resin infiltrant resulted in significantly greater aesthetic improvement than spontaneous remineralization mediated by saliva alone. Comparable superiority was also observed when resin infiltration was compared with remineralization therapy using fluoride varnishes. In most studies included in the meta-analysis, the hydrochloric acid etching procedure was performed three times, in accordance with the manufacturer's recommendations. In several studies, additional etching cycles were carried out to improve lesion penetration. However, comparison of these protocols remains difficult because individualized etching strategies have not yet been systematically investigated.

In another meta-analysis, Wittich et al. (2024) [42] evaluated the effectiveness of resin infiltration with and without prior tooth bleaching for the treatment of anterior teeth affected by dental fluorosis. The combined approach of tooth bleaching followed by resin infiltration produced significantly better aesthetic outcomes than bleaching alone. Moreover, patients treated with the combined protocol reported greater satisfaction and superior therapeutic outcomes than those treated with resin infiltration alone.

A clinical study conducted by Zotti et al. (2020) [43] evaluated the treatment of 200 fluorosis lesions in 30 patientsusing the Icon resin infiltration technique. In 86% of lesions, between one and seven etching cycles were required to achieve satisfactory masking of the enamel defects, whereas only a small proportion of cases required additional etching procedures. Postoperative dentin hypersensitivity was reported by only 11 patients, and all symptoms resolved spontaneously within 72 hours. The authors concluded that resin infiltration represents an effective treatment option for masking aesthetically unacceptable white enamel opacities associated with dental fluorosis.

A systematic review by Di Giovanni et al. (2018) [44] compared the effectiveness of microabrasion, tooth bleaching, and resin infiltration for the management of dental fluorosis. The review included data from 348 patients, representing at least 1,518 teeth with clinically visible fluorosis lesions. Bleaching alone was found to be more effective than enamel microabrasion in reducing the appearance of white opacities. However, both resin infiltration alone and resin infiltration combined with tooth bleaching produced superior aesthetic outcomes compared with bleaching alone. The authors concluded that resin infiltration is currently the most effective minimally invasive treatment for the aesthetic management of dental fluorosis.

Discussion

Both developmental enamel defects discussed in this review result in structural alterations of dental enamel. Depending on disease severity, these defects may affect the occlusal surfaces of teeth to varying degrees. Regardless of the extent of the lesions or whether the incisors are involved, both dental fluorosis and molar–incisor hypomineralization (MIH) produce visible aesthetic changes in the enamel of anterior teeth [15,32,33,45].

As discussed previously, oral health-related quality of life (OHRQoL) encompasses not only pain relief and the preservation of normal stomatognathic function but also orofacial appearance. Consequently, developmental enamel defects may negatively influence patients' psychosocial well-being because the altered appearance of their teeth differs from the aesthetic norms perceived by their peers. In some cases, visible enamel defects lead to reduced social interactions, avoidance of smiling, and withdrawal from social activities [5].

Patients affected by dental fluorosis often experience reduced self-esteem and impaired self-confidence owing to the presence of visible enamel opacities [36]. Likewise, individuals with MIH frequently report decreased oral health-related quality of life resulting not only from the compromised appearance of their teeth but also from dentin hypersensitivity and the need for repeated restorative treatment [24]. Additional psychosocial consequences include comparison with peers, negative comments regarding dental appearance, social exclusion, and emotional distress, all of which may further diminish quality of life [25].

An essential component of the management of developmental enamel defects is preventive therapy, including topical fluoride application and the use of casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) preparations. These interventions contribute to enamel strengthening and promote remineralization of superficial demineralized areas within the tooth crown. However, the available evidence indicates that these approaches are insufficient to eliminate aesthetically unacceptable enamel opacities and should primarily be regarded as preventive measures aimed at reinforcing weakened enamel and reducing the risk of dental caries [26,38,39].

Composite resin restorations may be indicated for MIH cases involving limited loss of dental hard tissues. However, they are generally not recommended for extensive defects because hypomineralized enamel exhibits inferior bonding characteristics compared with sound enamel, resulting in reduced restoration longevity. In cases involving substantial loss of tooth structure, particularly affecting the occlusal surfaces of permanent molars or large portions of anterior crowns, indirect full-coverage restorations are considered the treatment of choice [27,26].

Similarly, advanced dental fluorosis associated with extensive structural destruction is most appropriately managed using prosthetic restorations, including veneers or full-coverage crowns. Conversely, when fluorosis is limited to aesthetic enamel defects without significant structural loss, minimally invasive treatment modalities should be preferred [37].

Resin infiltration with the Icon system represents a minimally invasive therapeutic option for superficial carious lesions as well as developmental enamel defects associated with enamel porosity. Following appropriate surface preparation and hydrochloric acid etching, a low-viscosity resin infiltrant penetrates the porous enamel structure and is subsequently polymerized using a light-curing unit [13].

The available evidence indicates that this technique is effective in the treatment of enamel opacities associated with both MIH and dental fluorosis, providing therapeutic as well as aesthetic benefits. Penetration of the infiltrant into the porous enamel reduces lesion permeability, increases resistance to extrinsic staining and acid diffusion, reinforces the affected enamel, and effectively masks visible white opacities [12,14].

Several investigators evaluated treatment outcomes using standardized cross-polarized photography. Images obtained before treatment, immediately after the procedure, and during follow-up examinations enabled objective assessment of changes in lesion appearance and treatment stability. Cross-polarized

photography proved to be an effective method for documenting MIH lesions and evaluating the aesthetic outcomes of resin infiltration [14,29,30].

All studies included in this review concluded that resin infiltration is an effective treatment for developmental enamel defects. Favorable outcomes were consistently reported for both MIH [14, 28, 29, 31] and dental fluorosis [40–44].

Interestingly, in several studies involving MIH, patients expressed satisfaction with the aesthetic results even when investigators considered the clinical outcome to be suboptimal [29]. This finding highlights the importance of patient-reported outcomes when evaluating aesthetic dental treatments.

In addition to improving appearance, resin infiltration has been shown to reduce dentin hypersensitivity in patients with MIH, thereby contributing to improvements in oral health-related quality of life [14,29].

Several studies also demonstrated that white MIH opacities respond more favorably to resin infiltration than yellow or brown lesions. White lesions generally exhibited greater color improvement and blended more effectively with the surrounding healthy enamel, whereas darker lesions produced less predictable aesthetic outcomes [14,32]. These observations are consistent with the greater depth of hypomineralization and structural disorganization associated with yellow and brown enamel defects.

In contrast, the studies included in the present review did not demonstrate clear differences in the treatment response of yellow fluorosis lesions following resin infiltration. One possible explanation is that brown fluorosis lesions usually represent advanced stages of the disease characterized by extensive enamel destruction, for which restorative or prosthetic treatment is often more appropriate than minimally invasive techniques [37].

For dental fluorosis, resin infiltration may also be combined with tooth bleaching. Although bleaching alone improves the overall tooth shade and reduces color contrast between the enamel and fluorosis lesions, it appears to be less effective than resin infiltration. The best aesthetic outcomes have consistently been reported when both treatment modalities are combined [44].

By contrast, the evidence regarding the combined use of bleaching and resin infiltration in MIH remains limited, and further clinical studies are needed to determine the effectiveness of this treatment strategy.

Microabrasion has also been investigated as a minimally invasive treatment for developmental enamel defects [9,11]. In studies evaluating dental fluorosis, microabrasion, tooth bleaching, and resin infiltration all reduced the visibility of white enamel opacities. However, microabrasion consistently demonstrated the least favorable immediate aesthetic results and inferior long-term color stability compared with resin infiltration [40].

Conclusions

Resin infiltration with Icon is an effective, minimally invasive treatment for tooth discoloration caused by enamel demineralization and developmental enamel defects, including dental fluorosis and molar–incisor hypomineralization (MIH). In the management of MIH, Icon resin infiltration effectively reduces the visibility of demineralized lesions, improves the color characteristics of enamel, and decreases dentin hypersensitivity. In the treatment of dental fluorosis, resin infiltration provides superior esthetic outcomes compared with microabrasion or bleaching alone, and the achieved results demonstrate good long-term stability during follow-up. The Icon technique has a positive impact on patients' quality of life by improving smile esthetics. However, in cases of extensive enamel tissue loss, resin infiltration alone is insufficient and cannot replace restorative or prosthetic treatment. Therefore, it should be reserved for the management of superficial and moderately severe enamel lesions. The current body of evidence supports the efficacy and safety of the Icon resin infiltration technique. Nevertheless, further well-designed clinical studies with long-term follow-up, as well as comparative investigations evaluating different treatment protocols, are justified.

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