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Tam, C. P.; Manton, D. J.

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TREATMENT

Esthetic management of incisors affected with molar incisor hypomineralisation

C. P. Tam[1,2,3] · **D. J. Manton**[4]

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Abstract

Molar incisor hypomineralisation (MIH) is a structurally, aesthetically and sometimes functionally impairing condition that affects the enamel of first permanent molars and maxillary incisors. Incisor hypomineralisation can adversely impact the confidence of individuals with MIH. The management of MIH depends on the extent of hypomineralisation or structure loss and can range from ultra-conservative to invasive treatment modalities.

Keywords Hypomineralisation · Infiltration · Aesthetic · Structural · Whitening · Microabrasion

Overview

Treatment modalities	Indications
Remineralization via casein phosphopeptide-amorphous calcium phosphate (CPP-ACP)	White spot lesions and early carious lesions
External vital bleaching	Management of discolored teeth affected with MIH

✉ C. P. Tam
hello@clarencetam.co.nz

D. J. Manton
d.j.manton@umcg.nl

1 Skulpting Skool LLC, Auckland, New Zealand

2 New Zealand Academy of Cosmetic Dentistry, Auckland, New Zealand

3 Tam Dental Group Ltd., Auckland, New Zealand

4 Centrum voor Tandheelkunde en Mondzorgkunde (CTM)/Universitair Medisch Centrum Groningen (UMCG), Groningen, The Netherlands

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Treatment modalities	Indications
Surface microabrasion	Management of white spot lesions with more superficial extent
Resin infiltration	Management of hypomineralised enamel lesions Management of chromatic discolored lesions in combination with external vital bleaching
Macroreduction and esthetic layering	Management of severely discolored anterior teeth affected by incisor hypomineralisation Management of teeth with residual structural or visible hypomineralised defects in combination with or after other treatment modalities

Materials/instruments

- Aluminium oxide (27 micron as safer on dentin)
- Casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) crème
- Carbamide peroxide (Opalescence PF, Ultradent, UT, USA)
- Custom nightguard
- Bleaching trays
- Hydrochloric acid (HCl) (15%)
- Phosphoric acid (33%)
- Microabrasion formulations [(Opalustre, Ultradent Products Inc.), (Prema Compound, Premier Dental Company)]
- Diamond burs (cutting and polishing)
- Rubber dam as ideal isolation
- Gingival dam [(OpalDam, Ultradent, UT), (OptraGate, Ivoclar Vivadent)]
- Lip-retracting device (OptraGate, Ivoclar Vivadent) to be used with Gingival dam if rubber dam not possible
- Ligature ties used with rubber dam isolation
- Retraction cord
- Resin infiltrant (Icon, DMG, Hamburg, Germany)
- Self-cured addition silicone (Exaflex, GC, America)
- Opaquer (Masking Liner, Essentia, GC America)
- Composite material
- Abrasive discs (Sof-Lex Extra Thin, 3 M ESPE)
- HB lead pencil
- Diamond-impregnated silicone polishing discs and cups
- Aluminium oxide paste (Enamelize, Cosmedent)
- Felt plastic-backed single-sided disc (Flexibuff, Cosmedent) or Cotton Finishing Wheels (Final Shine, Clinicians Choice)
- Mandrel (Komet)

Procedure

Molar incisor hypomineralisation (MIH) is a developmental condition that affects the enamel of permanent first molars and often maxillary incisors resulting in structural, aesthetic and even functional impairment. The structural alterations occur in an infrequent manner and affect the incisors with varying intensity. Based on the color, nature and depth of incisor hypomineralisation, several treatment approaches are available for managing the esthetic impairment. Non- or minimally invasive techniques are preferred before invasive techniques to follow the protocol of responsible esthetics. The ideal treatment protocol for incisor hypomineralisation is sequential implementation of the current clinical approaches.

MIH occurs due to a deficiency in the post-secretory phase and is frequently misdiagnosed as other enamel developmental lesions. MIH lesions have irregular margins as the surface disintegrates after eruption. This causes accelerated caries development and dentin exposure, especially in molars. In incisors affected with MIH, the surface integrity of enamel is easily maintained due to the minimal functional masticatory forces on the labial surface. The palatal surfaces of incisors are seldom affected. In enamel hypoplasia, lesions with smooth peripheral margins are already present on the affected teeth at eruption.

Biomechanical considerations

In MIH, the integrity of enamel matrix formation is compromised at eruption causing a porous surface often with deficient volume, diminished physical properties and irregular microstructure. Microscopically, the enamel hydroxyapatite crystals have indistinct and unorganized rod sheaths along with a reported average 28% decrease in mineral content and a 3–15 fold increase in protein content that negatively affect adhesive bonding and microshear bond strength (Chay et al. IJPD, Crombie et al. Caries Res and J Dent). The authors purport that the decreased bonding performance was related to aberrant formation of microtags and the mode of failure primarily demonstrated as detachment of composite from the enamel (adhesive failure) with a minimum proportion of enamel-cohesive failure in the sample size. The latter is characterized on scanning electron microscopy as enamel rods broken internally and localized to the interrod regions. The increased enamel permeability can be considered as the origin of the bacteria into the dentin beneath clinically intact hypomineralised enamel (Fagrell et al, IJPD). MIH-affected enamel exhibits markedly decreased surface microhardness, increased protein content, increased carbonate and elastic modulus, and an increased tendency to absorb stains. It has been demonstrated that hypomineralised enamel lesions have the ability to remineralise especially if this effort is bolstered with agents that deposit the more stable complexes of fluoridated apatites and attain an improvement in mineral density (Crombie et al.). MIH-affected enamel exhibits markedly decreased surface microhardness and elastic modulus, and an increased tendency to absorb stains. In a healthy oral environment, the surface layer of defined hypomineralised enamel lesions can

remineralise and attain the mineral density and hardness of healthy enamel (Kumar et al. IJPD, Elhennawy et al. AOB).

Strategies for optimizing adhesive strength

Enamel affected with MIH is more porous and softer than healthy enamel. It has reduced mineral density that varies among and within affected teeth leading to compromised bonding (Crombie et al.). It is important to note that removal of the surface layer is beneficial prior to both mineralization and resin infiltration procedures as previous studies have shown poor response of hypomineralised lesions when the surface layer is present. Of note, Kumar et al. determined that the average thickness of the surface layer was 58 ± 29 microns. Coincidentally, they also found that application of 15% HCl (aq) for 120 s produced a mean MIH erosion depth of 58 ± 12 µm, demonstrating that surface layer removal can be achieved via mechanical or chemical means. A deproteinization pre-adhesive bonding treatment with 5.25% NaOCl (aq) for 1 min post-etching has been found to increase the microshear bond strength in some cases (Crombie et al.).

In a recent systematic review, it is noted that self-etching adhesives did not perform differently from total etch adhesives relative to bond strength (Lagard et al.).

Restorative considerations

The severity and extent of opacities on MIH-affected anterior teeth is highly variable and asymmetrical. Due to minimal direct functional forces on the labial surfaces of maxillary incisors, enamel breakdown is less prevalent. However, the associated poor esthetics affect the self-confidence of patients and compel them to seek esthetic treatment solutions. MIH lesions always begin at the DEJ and extend towards the enamel surface. Therefore, the extent of lesions should be considered during restorative treatment planning.

Staging protocols

Since incisor hypomineralisation is a structurally, aesthetically and emotionally-impairing condition, a meticulous protocol for staged treatment seems prudent. Generalized and mild cases of MIH should initially be treated with a non-invasive treatment modality like tooth whitening to reduce the color contrast between the lesion and the background. After this, remineralization using CPP-ACP along with microabrasion can be used to manage localized residual visible lesions, if suitable. The tooth should be evaluated with light transillumination with a dental curing light to identify the extent and depth of the lesion with superficial lesions appearing more translucent and lesions deep to the surface towards the DEJ denoted by a greater dark opacity. Superficial lesions can be evaluated for treatment using HCl-based microabrasive. Resin infiltration with TEGDMA can provide marked functional and visual improvement, if the previous methods prove inadequate.

The aforementioned techniques are non- or minimally invasive in nature. Ultimately, as a final option, macroreduction and composite layering can be performed to achieve satisfactory aesthetics, if resin infiltration is unsuccessful. These contemporary techniques enable a dentist to offer a staged treatment protocol that preserves maximum amount of healthy tissue for a satisfactory prognosis, which in turn gains the patient's trust.

Modalities of treatment in order of staging

Remineralization Remineralization is the increase in mineral density of a hypomineralised lesion. Casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) crème contains an active molecule that aids in the restoration of mineralization, porosity and morphology of hypomineralised lesions. It is used to treat hypomineralised white spot lesions (Crombie et al.).

The CPP-ACP or CPP-ACFP complexes accumulate on the lesion surface and maintain high ion gradients. This prevents spontaneous precipitation and facilitates a gradual ion release over time into the lesion body forming a neutral ion complex ($CaHPO_4$). CPP-ACP is effective for the remineralization of white spot lesions and early carious lesions with a long-term effect (Cochrane and Reynolds, Adv Dent Res).

External vital bleaching A wide range of lesion morphologies and colors are present in MIH. External vital bleaching is effective in improving the appearance of chromatically affected lesions with a marked background contrast. It is usually performed using carbamide peroxide in bleaching trays or custom nightguards (Fig. 1). It also works to reduce the contrast between the discolored, opaque lesion and its background color. Vital bleaching is a non-invasive treatment option for patients with MIH-affected discolored teeth. It provides visually satisfying results and boosts the patient's confidence. Commonly, a 10% carbamide peroxide solution (Opalescence PF, Ultradent, UT, USA) can be used safely with no significant negative impact on the mechanical and chemical properties of enamel.

Surface microabrasion Often, MIH lesions in anterior teeth are present throughout the entire thickness of enamel up to the dentino-enamel junction (DEJ). In such cases, mechanical and chemical microabrasion can result in only a limited reduction in lesion visibility. Kane introduced the concept of chemical removal of white spot lesions using 36% hydrochloric acid in 1926. In the 1970s, a rotary handpiece was used along with a mixture of 18% HCl, ether and hydrogen peroxide. Murrin

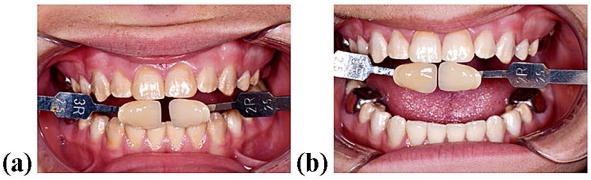

Fig. 1 External vital bleaching for generalised hypocalcified or hypomature enamel. **a** Baseline bleaching shade acquisition. **b** After 2 weeks of overnight vital bleaching in custom cervical seal trays with Opalescence

et al. used 36% HCl and pumice in a micromotor handpiece in 1982. Over the years, reduced acid concentrations were combined with abrasives suspended in a water-soluble mixture.

The use of surface macroabrasion with an extrafine diamond bur is suggested to facilitate lesion permeability and remove aprismatic enamel before chemomechanical abrasion. The modern microabrasion compounds are Opalustre (6.6% HCl + silica carbide abrasive) by Ultradent Products Inc. and Prema Compound (10% HCl + silica carbide abrasive) by Premier Dental Company. According to Sundberg, about 5–10 applications of microabrasive systems can cause 25–200 µm of enamel loss, which is considered clinically acceptable. About 1–10 repetitions of microabrasion using Opalustre on a tooth for 1-min cycles correspond to 25–200 µm of enamel loss.

Transillumination is useful for detecting hypomineralised lesions. When transilluminated, a dark or opaque lesion with poorly-defined borders indicates a deep lesion, while a translucent or light lesion with defined borders indicates a superficial lesion (https://onlinelibrary.wiley.com/doi/abs/10.1111/jerd.12602). If the lesion extent is superficial enough, microabrasion can be combined with surface enamel dissolution using Icon-Etch (DMG, Hamburg) to remove superficial stains and the surface layer, respectively. This can significantly improve the chances of favorable outcomes with resin infiltration.

The 'view from an extreme lateral aspect' technique is a diagnostic approach for judging the lesion depth from an extreme mesial or distal angle to visually confirm the penetration depth through the enamel volume. Microabrasion can show favorable outcomes with superficial white spot lesions (Fig. 2).

Post-treatment residual enamel microroughness and stain or plaque accumulation can occur with microabrasion. Natural enamel re-hardening was shown by Bertoldo et al. due to the presence of silica and chloride ions from microabrasion compounds.

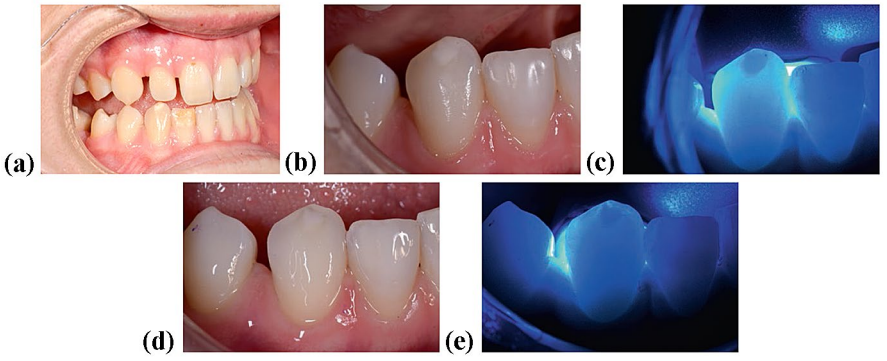

Fig. 2 Vital bleaching and microabrasion. **a** Hypomineralization on the buccoincisal aspects of teeth 42 and 43. **b** Overnight bleaching performed in custom trays using 10% carbamide peroxide. Pre-microabrasion situation on 43BI. **c** Transillumination showed partial lesion translucency suitable for microabrasion. **d** Post-microabrasion using Opalustre. Three cycles of 1 min each performed with moderate pressure. **e** Post-operative transillumination showing parts of the lesion that are subsurface in nature and proximal to the DEJ

A strong association exists between chloride ions and enamel re-hardening. The use of a microabrasion compound facilitates the development of a bioactive compound (Ca_3SiO_5) that can induce a novel apatite layer on etched enamel. Passive microabrasion should always be preferred over reductive polishing tools.

The simultaneous effects of mechanical, compressive and acid erosion on enamel rods form a surface layer similar to aprismatic enamel, which can mask subsurface lesions. Both HCl and phosphoric acid can be used to produce the 'abrasion effect' as they open up the surface inter-prismatic spaces without affecting the subsurface structure.

Resin infiltration Resin infiltration is a microinvasive technique used to treat hypomineralised enamel lesions due to their increased porosity. It includes a chemomechanical treatment component for removal of the highly mineralized surface layer facilitating infiltrant penetration and a restorative component that involves infiltration of a low viscosity resin into the body of the lesion via mechanical and active diffusion mechanisms under desiccated conditions. Resin infiltration is considered as the last non-invasive treatment modality for hypomineralised lesions. The extent of visual lesion improvement varies widely among cases and among teeth within a single oral cavity. Based on the presence of a deficiency or physical defect at the lesion site, resin infiltration can be performed with or without composite layering.

In case of chromatically discolored lesions, vital bleaching using a nightguard should be considered before increasing the color value of the lesion and the tooth. Such a combination treatment can produce favorable treatment outcomes. Prior to resin bonding, a stand-down period of 7–10 days is required to facilitate complete oxygen radical leaching from the teeth. An enhanced camouflaging ability of resin infiltration has been shown by Schoppmeier et al. when pre-bleaching of teeth is performed with 25% hydrogen peroxide solution about 2 weeks before the resin infiltration. This suggests a possible synergistic association between bleaching and infiltration.

Dental isolation and patient protection with rubber dam and ligature ties is the ideal standard of care before an adhesive restorative procedure. When anterior teeth have inadequate crown height, inappropriate angulation or posterior anchor points for rubber dam clamps in young patients, a localized gingival protection measure (OpalDam, Ultradent Products, Inc.) should be used. It can also be used in patients with a strong gag reflex along with a lip-retracting device (OptraGate, Ivoclar Vivadent).

Enamel etching with a 15% HCl solution causes some enamel loss. Preferably, HCl is used for complete removal of the hypermineralised surface layer. Even with increased repetitions of acid-etching, over-etching and significant enamel loss are difficult to achieve. In case of hypomineralised enamel, it is important to consider the thickness of the actual surface layer. The average enamel thickness in anterior teeth is 300–500 µm in the cervical area, 500–700 µm in the middle third and 700–1000 µm in the incisal third. Commonly, etching cycles are performed in sets with an average of 2 and 4 cycles per set. With this etching pattern, there is an initial erosion depth pattern of approximately 34 µm after the initial 2 min cycle. Each subsequent cycle increases the depth of erosion by 13.28–15.16 µm with an average

reported of 77 µm erosive depth. The actual depth of penetration of infiltrant ranges greatly in the literature with a high value of up to 2000 µm in resin penetration in an in vitro model (9), and thus the total permeation of resin is affected by both the erosive depth achieved into the lesion and also the intrinsic infiltration ability of the monomer in the resin infiltrant, which is related to molecular weight.

Enamel surface corrosion results in removal of the hypermineralised layer and provides access to the porous body of the hypomineralised lesion. This aids the infiltrant to reach the subsurface region. During the procedure, the optical refraction of enamel is altered. The corresponding reflective index of enamel is inversely proportional in nature and makes the teeth and lesions appear whiter than baseline during treatment.

For resin infiltration, TEGDMA is the monomer of choice. It requires pretreatment with ethanol for lesion desiccation. Apart from optical and visual benefits, resin infiltration also provides physical advantages to hypomineralised enamel. It enhances the microhardness and resistance to demineralisation as compared to resin-infiltrated carious enamel. Three applications of the resin infiltrant on average are sufficient to achieve it. Resin infiltration with Icon (DMG, GmBH, Germany) provides favorable optical results. To avoid staining of resin-infiltrated teeth, increased awareness about home hygiene, regular professional hygiene visits and diet by the patient is essential (Fig. 3).

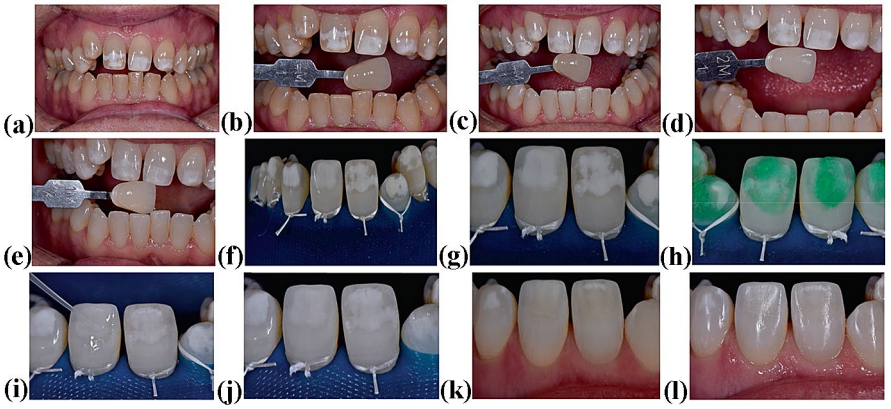

Fig. 3 Resin infiltration for achromatic enamel dysplastic spot lesions. **a** Baseline showing banding on the buccal aspects of maxillary teeth. The white intensives are more visible and intense on anterior teeth. **b** Baseline bleach shade. **c** Bleach shade check after 3-weeks of overnight bleaching with Opalescence. **d**, **e** Bleach shade check after 1 month, 3 weeks and 2 months, 3 weeks of overnight bleaching, respectively. **f** Baseline before resin infiltration with Icon. (g) Cross-polarized photo taken with Polar Eyes (Bioemulation, Germany) showing true extent and intensity of internal hypomineralisation. **h** Placement of 15% HCl on tooth surface for 2 min before thorough rinsing with water for 1 min and air drying. **i** Surface application of ethanol for 1 min (Icon) and dessication. The etch-rinse-dry-ethanol-dry cycles completed in over 4 cycles. **j** Situation before TEGDMA-based resin infiltration: 2 cycles of 3 min scrub and dwell, air thin, floss, 40-s cure, reinfiltrate, 3-min dwell time, air thin, floss, 40-s cure. **k** Immediate postoperative unpolarized and cross-polarized photos showing reduction of intensives with sites of residual hypocalcification. **l** 1-week post-infiltration photo showing marked esthetic improvement

Macroreduction and esthetic layering Macroreduction is an invasive treatment modality that can be used alone or in combination with the afore-mentioned procedures. Performing macroreduction and esthetic layering in a minimally invasive way after using the other techniques can provide a maximal esthetic result. It is also an effective method for the treatment of young permanent incisors affected by MIH.

Occasionally, macroreduction and esthetic layering can be performed after the minimally invasive procedures to correct residual structural or visible defects. It aids in physical elimination of the lesion and in gaining space for subsequent composite layering or indirect procedures. Rubber dam isolation and retraction cord placement are mandatory to facilitate the prognosis of the restorations.

Macroreduction and esthetic layering is an irreversible restorative technique requiring regular maintenance and replacement as composite restorations have limited longevity. Meticulous use of starburst or infinity bevels is needed to increase the surface area for bonding and blending of the resins into the adjacent normal enamel. For improving micromechanical retention before the adhesive procedure, surface layer removal/preparation and decontamination can be done using particulate micro-air-abrasion. If composite layering is required, development and photographic recording of a color map is essential before administering dental anesthesia to ensure satisfactory matching of the tooth shade in pre-dehydrated conditions.

Restoration of tooth shape is important in case of a deficiency in the outline form or primary anatomy of the affected tooth. The palatal or lingual shelf can be developed with a guided (diagnostic wax-up) or freehand method. The palatal aspect up to the facio-incisal line angle of the wax-up is recorded with self-cured addition silicone (Exaflex, GC America). An achromatic or chromatic, milky-white translucent or semi-translucent enamel-like composite is used to form the palatal shelf with an average thickness of 0.3 mm. It should approximate the palatoproximoaxial angles of adjacent teeth to provide sufficient space for composite layering on the facial surface.

To visually camouflage or occlude the discolored regions of tooth preparations, thin layers of opaquers (Masking Liner, Essentia, GC America) can be applied. The opaque shades should resemble the pre-dehydrated shade of the cervical area of the tooth as dentin and therefore, hue, is most visible at these sites. Anatomic sculpting of the dentin layer includes creation of dentin mamelons with 2–3 dominant lobes on the incisal aspect of anterior teeth. The mamelons are splayed into smaller subheads with subtle connections of small strands of these subheads to the incisal edge at random intervals.

Thickness of composite layers should be judged from the incisal view as it allows space preservation for subsequent layers and prevents ‘overbuilding’ of the facial aspect of the tooth. Application of a clear translucent material in the incisal region is necessary to make the dentin mamelons visible in the final restoration. The bulk of the incisal edge is usually formed using a clear or amber translucent material to provide space for the application of a grey translucent or blue translucent material on

the proximal or proximo-incisal aspects of the incisal third. It is important to leave sufficient space for the enamel layer by not overbuilding the bulk layer.

Occasionally, the color map can show small hypocalcified spots, streaks or clouds, crack lines and regions of increased chroma in the adjacent teeth after curing the translucent layer of the affected teeth. At this time, stains or tints can be applied sparingly on the affected teeth. Increased appearances of hypocalcification in adjacent teeth should be ignored as dehydration alters the refractive index of enamel. The enamel layer of the restoration contains either a single chromatic layer or two blended layers including a cervical layer of chromatic enamel and an incisal layer of achromatic enamel. It is built and sculpted using sufficient material and volume at the transitional facioproximal line angles. It is of paramount importance to make sure that adequate visual 'separation' of teeth and accurate reproduction of the primary tooth anatomy are achieved.

A series of abrasive discs (Sof-Lex Extra Thin, 3 M ESPE, USA) are used to refine the primary anatomy of the restoration. A red stripe fine diamond bur is used to define the three planes of facial reduction and remove cervical overhangs. It creates a slightly concave to flat area in the incisal to middle thirds of the facial plane between the facioproximal line angles. An HB lead pencil is used to plan the secondary anatomy. The anatomy is carved on the tooth surface as a contouring map with a series of burs (needle-point diamond, football-shaped diamond and chamfer) resulting in a smooth, wave-like surface reflecting the lobes of the tooth. After developing the primary and secondary anatomy, medium and fine Sof-Lex discs are lightly pressed into the depressions to remove the macro-scratches.

While developing the tertiary anatomy, perikymata are created on the surface using green-stripe or coarse diamond burs by running them in a single direction across the tooth with light pressure and at stall speed. Polishing of the restoration is initiated using a pre-polisher. A high shine is achieved with diamond-impregnated silicone polishing discs and cups. A 1 µm aluminium oxide paste (Enamelize, Cosmedent) and a felt plastic-backed single-sided disc mounted on a mandrel (Flexibuff, Cosmedent) impart the final luster to the restoration (Fig. 4).

Pitfalls and complications

- Initial tooth whitening in generalized and mild cases results in elimination or reduction of the chromatic aspects of the lesions.
- Macroreduction of MIH lesions in severely affected teeth to expose more normal tissue for effective bonding can result in loss of more than 2/3 of the tooth surface enamel.
- Resin infiltration with Icon (DMG, Hamburg) is more susceptible to staining than other restorative options.

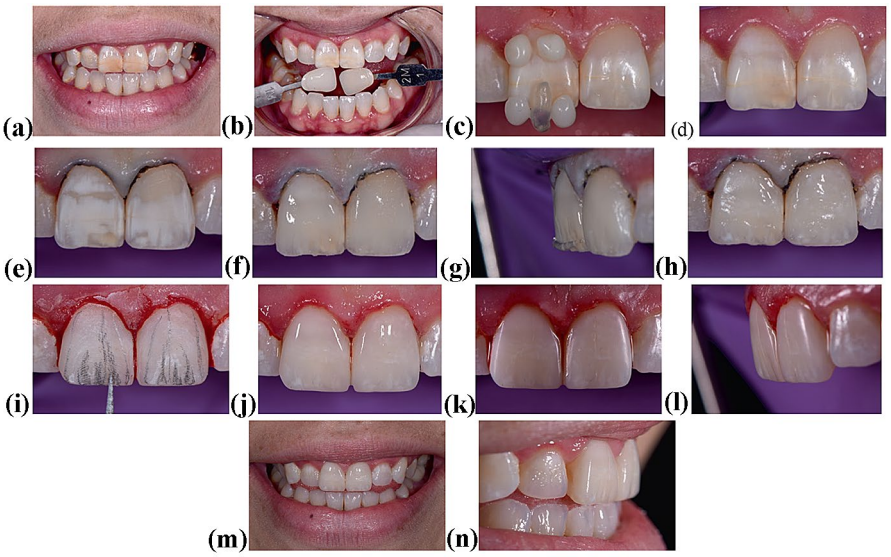

Fig. 4 Macroreduction and composite layering. **a** Baseline with chromatic incisor hypomineralisation and stained comminuted hairline fractures. **b** After 4 weeks of overnight bleaching with Opalescence. **c** Baseline before composite veneer placement on teeth 21 and 11. Shade selection via the shade button method with various shades of enamel and dentin and an iridescent blue effect shade from Vit-l-escence (Ultradent, UT). **d** Split rubber dam isolation before composite veneer placement. **e** Veneer preparation with micro-air-abrasion using 27 µm aluminium oxide while maintaining the bulk of preparation within enamel. **f** Following a total etch adhesive application (Peak Universal Bond (Ultradent Products Inc., UT), application of A1 (Vit-l-escence) for the dentin layer. **g** Incisal irregularities of the dentin lobules filled with an iridescent blue translucent material (irB, Vit-l-lescence). **h** White tint applied to the restoration to allow it to blend with the adjacent natural teeth. **i** Primary and secondary anatomy developed after complete placement of the enamel layer (Pearl Neutral, Vit-lescence). **j** After finishing and polishing, the adjacent teeth become brighter with more intense opacities due to dehydration. **k** The restorations' internal effects can be seen under indirect light. **l** Oblique view showing accurate secondary anatomy. **m**, **n** Post-operative reassessment showing acceptable esthetics

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