

When (and when not) to use the Dahl Concept

Arijit Ray-Chaudhuri,^{*1} Timothy Brown,² Emma Ray-Chaudhuri,³ Simon Critchlow,⁴ Raj Dubal,⁵ Kushal Gadhia⁶ and Sara Tabiat-Pour⁷

Key points

The Dahl Concept is a predictable treatment modality involving the triad of tooth intrusion, tooth extrusion and mandibular distalisation.

General considerations include age, occlusal adaptability, skeletal and incisal pattern, history of temporomandibular disorders, parafunctional habits and altered bone metabolism.

Local considerations include the presence of retainers/splints and implants/fixed prostheses, as well as periodontal status, restoration choice and restoration material and thickness.

Abstract

The Dahl Concept describes the re-establishment of occlusal contacts after the provision of a planned localised appliance or restoration in supraocclusion. Initially developed to create space for prosthetic rehabilitation of anterior teeth suffering from localised wear, the principle has later been successfully applied to a variety of situations, including the Hall technique and resin-bonded bridges cemented in supraocclusion. Despite high levels of success seen in the relevant literature and widespread adoption in specialist care, the wider profession appears to be far more cautious in its use. This article aims to provide a brief summary of the Dahl Concept and discuss the local and general factors that influence its successful implementation in the hope of promoting its increased adoption by the broader dental profession.

Introduction

The Dahl Concept describes the relative axial movement of teeth to re-establish interocclusal contacts after a localised fixed or removable appliance or restoration(s) is placed in supraocclusion.¹ The use of a dental prosthesis placed in supraocclusion to promote desired tooth movements has a long history of use in orthodontics, with anterior bite planes being used in overbite reduction in growing patients for decades.² However, it was Anderson in 1962 who first demonstrated the applicability of this concept for prosthetic dentistry in adult patients, by cementing single first molar metal onlays unilaterally that were 0.5 mm high.³ Anderson then noted

re-establishment of occlusal contacts within 1–2 months.

In 1975, Dahl and colleagues explored this area further with the restoration of localised anterior maxillary tooth wear on an adult patient.⁴ An 18-year-old subject was provided with a 2 mm thick removable anterior metal bite plane to be worn 24 hours a day (Fig. 1). The posterior teeth were initially discluded but they re-established occlusal contacts over eight months. Thus, a space equivalent to the thickness of the appliance was left anteriorly. This allowed subsequent restoration of the worn anterior teeth with conventional indirect restorations, but with significantly less tooth reduction required compared to that which

would have been necessitated in the original occlusal relationship.

Follow-up studies by Dahl and colleagues investigating the same technique monitored implanted radiopaque reference markers over serial radiographs, allowing them to conclude that the mechanism for localised interocclusal space development was via extrusion of the posterior discluded teeth and intrusion of the anterior teeth in contact with the bite plane and not due to a change in the inclination of the teeth.^{5,6,7,8,9} In some cases, this passive extrusion occurred faster than was achievable using active orthodontic therapy, leading to the belief that some degree of mandibular distalisation was also occurring.^{1,10} Consequently, the authors

¹Consultant in Restorative and Implant Dentistry, University Hospitals Sussex NHS Trust, UK; ²Speciality Dentist Restorative Dentistry, Dundee Dental Hospital and School, UK; ³Specialist in Paediatric Dentistry, Graystone Referral Centre, Sussex, UK; ⁴Consultant in Restorative Dentistry, Great Ormond Street Hospital, UK; ⁵Consultant in Restorative Dentistry, Bart's Health NHS Trust, UK; ⁶Consultant and Honorary Senior Lecturer in Restorative Dentistry, Eastman Dental Hospital, UK; ⁷Consultant in Restorative Dentistry, Guy's and St Thomas' Trust, UK.
*Correspondence to: Arijit Ray-Chaudhuri
Email address: aj@graystonereferral.com

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Fig. 1 a, b) Photographs displaying anterior metal removable bite plane placed in supraocclusion used to treat localised anterior tooth wear, as described by Dahl and his team. Reproduced with permission from Dahl *et al.*, 'An alternative treatment in cases with advanced localized attrition', *Journal of Oral Rehabilitation*, 1975, John Wiley and Sons⁴

of this paper would describe the original Dahl appliance as acting as an anterior deprogrammer in addition to it causing the intrusion and extrusion of teeth.

Therefore, the consensus from the scientific literature appears to describe the mechanism as the following triad:

- Intrusion of anterior teeth
- Extrusion of posterior teeth
- Mandibular distalisation.

Goldstein, however,¹⁰ favours the minority view that the primary mechanism is explained through multi-factorial adaptation within the condyle-fossa complex.

The application of Dahl's findings has continued to evolve over the subsequent 45 years, utilising the improved strength and reliability of adhesively bonded dental materials. This saw a trend away from the original removable appliance to adhesively fixed cemented bite planes, with the added benefit of eliminating patient compliance issues.^{9,11} As clinicians recognised the predictability of the result, a further trend moved clinicians away from the aforementioned two-stage approach to a one-stage approach. The latter now predominates in clinical practice, with planned definitive restorations commonly placed in supraocclusion without the preliminary use of a fixed or removable Dahl appliance. Thus, Dahl appliances *per se* are rarely used, but the Dahl Concept remains and is valued by the authors.

The literature shows that multiple techniques can be successfully employed using a variety of

materials, including resin composite, gold, non-precious metal alloys and porcelain.¹ Despite the potentially high aesthetic outcomes, the authors do not favour the latter material by itself (without a sub-structure) due to its brittleness in thin section, difficulty of chairside repair and adverse wear characteristics for any opposing natural teeth when finished suboptimally.

Despite a significant amount of research on the Dahl Concept arising from the UK,^{1,10} there appears to be a general lack of uptake outside of secondary care. This may be due to an absence of exposure to the technique at an undergraduate level, a lack of familiarity with the recent literature, concerns over the development of complications or because of poor remuneration for extensive treatment reducing its provision in primary care.¹

Another significant issue is that the Dahl Concept challenges the dogma that restorations should either conform to the current occlusion or be completely reorganised into an 'ideal' occlusion (where maximum intercuspation is coincident with the centric relation of the mandibular condyles). This ongoing controversy is exemplified by the fierce debate generated in response to a recent opinion article exploring a less prescriptive approach to occlusion management by Davies *et al.*^{12,13,14} Justifiably, this debate may reinforce non-specialists' reticence to stray from adhering to either the conformative or reorganised approaches, especially in our currently litigious climate.

However, to help overcome this, it is important to highlight the high levels of success^{1,15} and patient acceptance of the Dahl Concept in the literature.^{1,16,17} When used for the management of localised anterior wear, re-establishment of occlusal contacts occurs in 94–100% of cases over an average of six months (range 1–24 months).¹ Thus, the Dahl technique is commonly used by the authors in a variety of primary and secondary care settings, especially in the management of localised tooth wear. Therefore, it is important that dentists understand when, and when not, to use the Dahl Concept in the management of localised tooth wear, as well as the Hall technique and adhesive bridges.

General factors

Age

There is no upper age limit for use of the Dahl Concept, with it successfully being used in many older patients, including patients in their seventh and eighth decades of life.^{18,19} However, it is important to be conscious that older patients are more likely to present with heavily restored dentitions, reduced bone remodelling capacity (be it physiological, pathological or secondary to medication) and a lower adaptability or tolerance to occlusal changes, all of which may have a significant impact on their treatment complexity and prognosis of treatment. Consequently, the authors favour the use of the Dahl Concept in younger patients and use the concept with greater caution in older patients due to the indirect effects of age on the dentition, rather than the patient's age *per se*. Older patients may present with heavily restored teeth, teeth with thin cusps surrounding old plastic restorations and tilted or over-erupted teeth. When these teeth re-occlude, some minor occlusal adjustment may be required if unfavourable interferences are present towards or at the end of the tooth movement. Thus, the authors favour more careful monitoring of the occlusion in such older patients, or indeed any patient with similar posterior teeth.

In addition, younger patients usually exhibit more rapid tooth movements when orthodontic forces are applied, resulting in comparatively shortened treatment times.²⁰ Another benefit may be that of younger patients having a more recent personal or social familiarity with orthodontic treatment, aiding proposed treatment acceptance (Fig. 2).

The Hall technique utilises the Dahl Concept and its success is well recognised in the paediatric literature.^{21,22} Preformed stainless



Fig. 2 a) This adolescent patient presented with bilaterally missing maxillary lateral incisors. b, c) After extractions and orthodontic treatment, they were left with upper lateral incisor spaces to be restored with a four-unit anterior adhesive bridge (Bristol design). They had tolerated orthodontics well, had an otherwise unrestored dentition and required anterior tooth replacement and thus was considered a highly suitable candidate for the use of the Dahl Concept

steel crowns are cemented onto unprepared carious molars, sealing in the caries with a view to arresting its progression. The lack of preparation means a less invasive experience for the child but results in the crown being placed in supraocclusion (see Fig. 3), with no reports of associated temporomandibular disorder (TMD) development²³ or lack of occlusal re-establishment.^{21,22}

Occlusally adaptive patients

Clinical experience dictates that occlusal adaptation is far more complicated than the mere technical process of providing the 'ideal' occlusion. Rather, it represents the interaction of a patient's modulation of oral somatosensory inputs by the central nervous system and their natural sensorimotor neuroplasticity.²⁴ While the traditional occlusal philosophies provide a framework for planning a predictable and comfortable bite from the patient's perspective, it has been suggested that the 'ideal' occlusion should really be re-framed as any occlusion the patient is able to adapt to.¹²

The authors agree with this view and indeed most experienced clinicians have seen numerous patients with far-from-conventional occlusions following restorative or orthodontics treatment who display no adverse symptoms. A potential explanation for the high acceptance rates of occlusal changes in both orthodontic and 'Dahled' patients may be the slower full mouth occlusal changes delivered (akin to 'evolution'), allowing the patient to physiologically adapt slowly over time, versus the more extreme 'revolution' of a conventional full mouth rehabilitation.¹²

Consequently, patients with adaptive problems represent the 'occlusally hypervigilant' few (for example, they constantly check their teeth), rather than the majority. If a patient is considered to have hypervigilance, then the clinician should proceed with cautious reversible stages to allow the new occlusion to be tested and consented to before any definitive treatment is undertaken, or, alternatively, not proceed at all with treatment but rather refer to a specialist in prosthodontics or restorative dentistry (Fig. 4). Examples of adopting a cautious approach in using the Dahl Concept in such patients includes returning to a form of Dahl's original removable appliance and/or adopting a two-stage process and confirming patient function and acceptance before proceeding with the definitive restorations.

However, at its most extreme presentation, this outlier vigilant group of patients may display occlusal dysaesthesia, first described

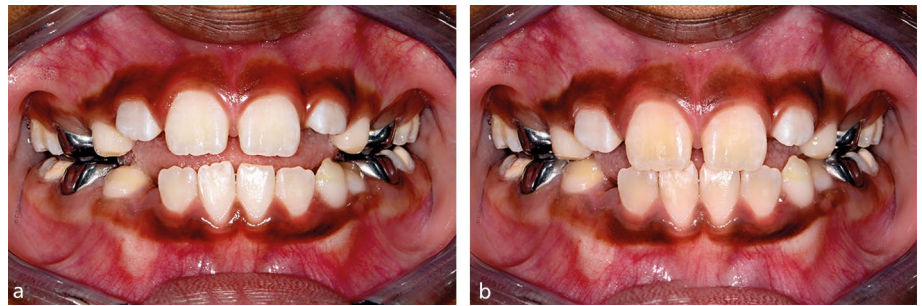


Fig. 3 a) An 8-year-old child required stainless steel crowns on all of their second deciduous molars due to enamel hypoplasia. These were placed using the Hall technique in supraocclusion without local anaesthesia or tooth preparation. Note how the patient was only biting on these two treated occluding pairs of molars. b) After three months, contact on the first molars and central incisors was re-established



Fig. 4 a) This patient was seeking a fixed replacement for his worn and mobile retained 53, with evidence of significant root resorption and an ectopic 13 visible on the cone-beam computed tomography scan. He described himself as very occlusally aware and had declined orthodontic treatment and management of his ectopic 13 for this reason in his teenage years. b, c) The retained 53 was extracted and a no-preparation temporary adhesive bridge placed to assess his adaptive capability to the Dahl Concept due to known occlusal hyper-vigilance. d) He slowly adapted to his new occlusion, displayed by the interocclusal space closure on the righthand side over the next three months and has elected to have a long-term adhesive bridge cantilevered from the 14

as 'Phantom Bite' by Marbach in 1976.²⁵ While rare (no prevalence data exist), clinical case reports describe any interventive treatment of these patients becoming an unhappy, time-consuming affair, with ultimately futile and potentially litigious outcomes.^{26,27}

It is important to appreciate that in these patients, the dental symptoms represent the manifestation of an underlying psychiatric condition and no elective dental treatment should be provided. Early referral to appropriate secondary care specialists for formal diagnosis, counselling and assessment

by psychiatric liaison services is required.

A summary of characteristic occlusal dysaesthesia presentation signs and symptoms are shown in Box 1.

Skeletal and incisal pattern

The underlying skeletal and incisor pattern are important to identify before adopting the Dahl Concept. A patient's skeletal relationship in general tooth wear, however, may not be immediately apparent, as patients habitually posture their mandible forward to develop anterior occlusal contacts.

Box 1 A summary of common occlusal dysaesthesia presentation signs and symptoms.

- Females five times more likely to be affected than males
- Typically present in fourth, fifth or sixth decade
- Often highly intelligent, educated and articulate
- Describe a nonspecific occlusal discomfort persisting for more than 3–6 months
- Adamantly persist that the occlusion is the primary or only cause of their complaints
- Unwilling to consider other causes of their complaint, especially underlying psychiatric conditions when raised
- Strong negative emotions about previous dental treatment
- Strong positive expectations of future dental treatment
- Multiple previous unsuccessful occlusal modifications
- A disparity between the objective occlusal findings and the subjective perception of the findings
- A detailed description of their occlusion or desired treatment, possibly with the use of medical or dental terminology
- May present with detailed notes, records and models.

Information from Jagger and Kelleher^{26,27}



Fig. 5 a, b) This shows the pre-operative situation of a dentally intelligent doctor with localised anterior tooth wear, a discoloured 11, a long-standing Class III incisal relationship and unilateral crossbite. c, d) He declined orthodontics, orthognathic treatment and full mouth rehabilitation. He wished to adopt a less invasive approach resulting in composites placed in supraocclusion using the Dahl Concept on 11, 21 and 22 only, which also disguised the discoloured 11. e) Note the full re-establishment of the posterior contacts which took approximately 15 months

Furthermore, patients with a Class II division 1 or 2 incisal relationship by definition have their lower anterior teeth contacting behind the cingulum plateaus of the upper anterior teeth.²⁸ Thus, mandibular distalisation resulting from the use of the Dahl Concept anteriorly can cause the incisal edges of their lower anterior teeth to occlude further posteriorly than their original position and increase their overbite significantly. This can result in a more apparent Class II skeletal relationship, incomplete overbite, or trauma to the palatal gingivae with resultant pain, swelling and speech, facial and/or masticatory changes.

The provision of anterior restorations in supraocclusion may act as a form of deprogrammer in these patients, resulting in potentially significant repositioning within the joint and subsequent occlusal derangement. An example of this phenomenon and subsequent management was described by Coulter,²⁹ who highlighted a patient who went from having

a 4 mm to a 9 mm overjet after composite additions to their anterior teeth, suggesting a significant undiagnosed underlying Class II skeletal relationship.

When using composite resin to restore anterior worn teeth, there is conflicting evidence regarding which incisal relationship is linked to higher failure rates. Redman *et al.*³⁰ investigated survival of anterior restorations up to six years and found that study subjects with a Class II division 2 incisor relationship had a statistically higher failure rate.³⁰ This may be explained by these patients often exhibiting a restricted envelope of function with steep disclusion of posterior teeth and heavier functional or parafunctional loads on anterior teeth, resulting in heavier loads on the final restorations. Gulamali *et al.*¹⁹ found that subjects with a Class III incisal relationship had a better survival than other incisal relationships at ten years. Conversely, Milosevic *et al.*³¹

found that a Class III incisal relationship was associated with a lower composite survival.

Due to the conflicting literature outlined above, the authors have no clear preference for the underlying incisal or skeletal relationships when using the Dahl Concept regarding restoration survival. Nonetheless, due to the ability of 'Dahled' anterior restorations to act as a deprogrammer and distalise the mandible, the authors recommend proceeding with caution in patients with a Class II skeletal profile. Such patients should have upper and lower study casts mounted on a semi-adjustable articulator using a facebow and a pre-centric occlusal record to identify their underlying non-habitual incisal and skeletal relationship. These patients may be unsuitable for using the Dahl Concept and instead may require a multi-disciplinary approach with assessment and treatment from orthodontics and/or oral and maxillofacial surgery (Fig. 5).



Fig. 6 a, b) This teenage patient had hypodontia affecting the lower second premolars bilaterally. They were provided two posterior adhesive bridges cantilevered mesially from their unrestored lower first molars. c, d) They were aware of a significant bruxing habit and had evidence of moderate attritional tooth wear on their canine teeth, with matching wear faceting noted on lateral excursions. Due to the combination of posterior adhesive bridges – prone to higher failure rates than anterior bridges – and bruxism, they were alerted to the increased risk of restoration failure as part of the consent process

TMD and orofacial pain

Use of the Dahl Concept does not appear to induce longstanding TMD in previously asymptomatic patients. Any temporomandibular joint discomfort appears to affect only a small number of patients and resolves rapidly.¹⁹

However, it is widely recommended to stabilise any pre-existing TMD symptoms before undertaking a definitive rehabilitation where an increase in the occlusal vertical dimension (OVD) is necessary, otherwise the condition could be exacerbated.³² Where an increase in OVD is required in TMD patients, some authors recommend using a removable appliance at the desired new OVD to both help stabilise their TMD and trial patient tolerance of the new OVD.³² The authors favour a similar approach of stabilising TMD before using the Dahl Concept but patients should be advised that their symptoms may transiently return.

If a patient's TMD cannot be stabilised, then the authors recommend proceeding with caution or not at all. The authors feel such a patient ought to be advised verbally and in a written report that the proposed treatment will have no positive effect on their TMD and may potentially make it worse. Similarly, patients with controlled orofacial pain can have the Dahl Concept used, with

appropriate cautionary advice, but patients with unmanaged facial pain should not be treated via this approach.

Parafunctional habits

Naturally, patients with current or historic parafunctional habits are overrepresented where use of the Dahl Concept may be indicated due to the effects of attritional tooth wear.

While not a strict contraindication, parafunctional habits, such as bruxism and nail biting, will likely increase the risk of restoration failure due to wear, chipping, fracture or debonding.

However, the same applies for many types of restorations in these patients when a conformative approach is used.^{33,34} Patients who demonstrate the presence of these habits should be warned of the potential implications regarding increased restoration failure rates and future maintenance costs (Fig. 6).

The dentist can help to mitigate these risks by choosing more durable materials (for example, gold for posterior onlays instead of resin composite) and the provision of a protective splint at the completion of treatment. The use of botulinum toxin into the muscles of mastication can also be considered as a novel adjunctive technique.³⁵

Altered bone metabolism

The authors are unaware of data regarding the use of the Dahl Concept in patients with altered bone metabolism. Nor are we aware of data about its use in patients having undergone radiotherapy to the head and neck region, or in patients taking medications that risk medication-related osteonecrosis of the jaws, such as bisphosphonates, RANKL (receptor activator of nuclear factor- κ B ligand) inhibitors and anti-angiogenic medications. These conditions and therapeutic treatments potentially alter the physiological process required to remodel bone around the teeth which are essential to the adaptive changes required for the Dahl Concept to work. Thus, the Dahl Concept should not be provided in such patients without the engagement of the patients' physicians and judicious risk-stratification.

Local factors

Retainers and splints

The concurrent use of any form of fixed retainer or periodontal splint while using the Dahl Concept should be avoided as it will likely inhibit the ability of the teeth to intrude or extrude and so create space or re-establish occlusal contacts (Fig. 7).

The authors, however, commonly place adhesive bridges following orthodontic treatment. This mandates immediate orthodontic retention to prevent unwanted tooth movements but will also stop the full re-establishment of occlusal contacts. These patients are advised that they may be supraoccluding on the adhesive bridge retainer indefinitely. The authors have not noted any adverse outcome in their experience.

If the treating dentist was keen to avoid this possibility, then the Dahl Concept would have to be used in a two-stage process, where the abutment teeth were restored with a thickness of composite matching the final thickness of the adhesive bridge retainer placed before undertaking orthodontics. An alternative to this approach is to place the composite on the opposing tooth rather than the tooth to be used as the bridge abutment. This avoids having to remove the composite from the bridge abutment tooth. It can also be beneficial to request the abutment teeth are intruded by the requisite amount during orthodontics. These approaches would allow the treating clinician to later place an adhesive bridge that conformed to the patient's occlusion.

It should be noted that it may be beneficial to provide a sectional Essix-style retainer to patients to protect anterior restorations while waiting for the posterior teeth to extrude, particularly in active parafunctional patients. Once posterior contacts are established, a full coverage protective splint – such as Tanner or Michigan splint – may then be constructed.

Implants and fixed prostheses

The original definition of osseointegration is 'the direct structural and functional connection between the living bone and surface of a load-bearing implant'.³⁶ Although a modern definition of the phenomenon has superseded this to describe the process as a foreign body reaction, nonetheless, for an endosseous implant to be successful, there must be no interceding soft tissue between the bone and the implant surface. Thus, implant fixtures act similarly to an ankylosed tooth and do not have the potential to intrude or extrude like teeth that possess a periodontal ligament. Therefore, a careful assessment must be undertaken to assess the number and position of implants in the patient's mouth as the consequences are very dependent on the number of implants versus teeth to be 'Dahled'.

For example, if the patient is fully dentate, with anterior 'Dahled' restorations and a single implant-retained crown on a terminal tooth, the authors would expect there to be little or no consequences for the implant or its crown. This is because although the implant-retained crown will not extrude, the opposing tooth will extrude to maintain contact and/or the mandibular distalisation will create contact between antagonist teeth.

In contrast to this, an implant restoration adjacent to 'Dahled' restorations will potentially create a step in the incisal or occlusal level. This may or may not be significant in appearance or function and thus, patients should be pre-warned that a new implant prosthesis may be required as part of the proposed treatment.

Finally, an implant's lack of periodontal ligament means there is significantly reduced tactile feedback to guard against excessive occlusal force generation.³⁷ Thus, using the Dahl Concept directly opposite implant restorations must be done with caution. In theory, the restorations would effectively and rapidly intrude against the implants with extrusion of other teeth and mandibular distalisation being unaffected. However, there



Fig. 7 a, b) This patient presented with an infra-occluded and resorbed 11 on a reduced periodontium, displaying currently stable generalised periodontitis stage 4 grade C and splinting of the lower anterior teeth. He had a severe gag reflex prohibiting the use of a removable prosthesis. c, d) 11 was extracted and a temporary adhesive bridge was placed conforming to the occlusion after preparation of 21 due to the presence of the splint. The 11 was eventually replaced with an implant and 21 was restored with composite

is risk of damage to the implant restoration, and in the worst-case scenario, to the implant fixture or teeth to be 'Dahled'.

A rare approach favoured by the authors if implant restorations are to be used is to request the dental laboratory to fabricate a provisional implant restoration with a completely flat metal occlusal surface to ensure the Dahl forces are directed apically leading to the required intrusive tooth movement. Prescribing full cusp anatomy on the provisional restoration carries a small risk that the tooth being 'Dahled' will tip rather than be intruded. When the intrusion is complete, the provisional implant restoration can be replaced for a definitive restoration, conforming to the new occlusion but with natural occlusal anatomy. Careful consent should be obtained and more frequent reviews considered if an implant restoration is to be used as the antagonist to teeth due to receive 'Dahled' restorations.

Periodontal attachment

Unstable periodontitis is a strict contraindication for using the Dahl Concept (Fig. 8). Secondary occlusal trauma is described as an injury resulting in tissue changes from 'normal or excessive occlusal forces applied to a tooth or teeth with reduced periodontal support'.³⁸ Increased occlusal loading of teeth to be intruded may cause or exacerbate pre-existing mobility and predispose them to unwanted and uncontrolled horizontal tooth movements.³⁹

Meanwhile, promoting extrusion of periodontally compromised teeth may cause them to extrude out of their bony housing, potentially leading to an undesirable increase in a tooth's crown-to-root-ratio, root exposure, dentine hypersensitivity or exposure of the furcal areas.

While periodontally stable teeth may be treated using the Dahl Concept, there is no



Fig. 8 a) This patient presented with avulsed 21 and 22 and wanted a fixed replacement but had suboptimal oral hygiene and unstable periodontitis. b, c) He was provided a temporary denture conforming to his occlusion while he established excellent oral hygiene and undertook non-surgical periodontal therapy. He will be offered two cantilevered adhesive bridges using the Dahl Concept once he has a diagnosis of stable periodontitis and the remaining bone on the abutment teeth and opposing teeth have been assessed

clear guidance on the remaining minimum bone or attachment levels before treatment, but some authors suggest that the remaining bone should support at least two-thirds of the root length as a minimum.³⁹ Sadly, this recommendation has no empirical basis aside from an *in vitro* study demonstrating significant additional periodontal ligament stress after 60% bone support is lost,⁴⁰ but the authors feel it represents a reasonable rule of thumb. Therefore, the risk of any potential undesirable consequences highlighted above must be considered carefully against the benefit of treatment before execution whenever compromised bone support is present.

Poyser¹ suggests the use of removable appliances when using the Dahl Concept to restore localised tooth wear in periodontally compromised patients. He suggests this allows for optimal interproximal cleaning and the splinting affect it offers ensures axial directing of occlusal forces, reducing the risk of unwanted horizontal movement or drifting.

Similarly, root resorption can also result in reduced attachment apparatus around teeth. In these teeth, the entire root surface may have a healthy periodontium and bony housing; however, the total amount of root structure is reduced. The prevalence of root resorption appears higher in patients who have undergone orthodontic treatment although the vast majority is mild to moderate.⁴¹ The authors recommend that serial radiography is undertaken for at least one year and combined with information from the clinical assessment to confirm that the resorption is not progressing. We consider that it is reasonable and safe to use the Dahl Concept in patients with mild root resorption although patients must be advised that there is a small risk that



Fig. 9 a, b) This adolescent patient was originally planned for an adhesive bridge mesially cantilevered from 24 after extraction of the canine due to ectopia. However, pre-debonding radiography illustrated advanced bone loss in the 23 region and advanced root resorption on 24, making it unsuitable for use of the Dahl Concept. c, d) The patient was provided with a composite on the diminutive 22 and a Kennedy Class III denture to replace the missing 23 after declining grafting and an implant

the resorptive process may be re-initiated by placing the tooth in supraocclusion, thus compromising its long-term prognosis. The authors do not recommend that the Dahl Concept is used on teeth with moderate or severe root resorption.

It is for the aforementioned reasons that the clinician must obtain a full periodontal

assessment, relevant radiographs of the teeth to be treated and ultimately, a periodontal/gingival diagnosis must be obtained before proceeding. The authors would also recommend a low threshold for undertaking radiographic assessment of the treated and antagonist teeth before using the Dahl Concept (Fig. 9).

Fixed versus removable restorations

In general, the authors prefer a fixed or direct one-stage approach when employing the Dahl Concept, mainly due to the benefit of overcoming the inherent risk of patient non-compliance associated with removable appliances. However, where there is any concern regarding patient adaptation to an increased OVD, then removable approaches may be beneficial to trial any changes without undertaking any potentially time-consuming, expensive, or destructive procedures.

Examples where a removable approach – together with more frequent reviews – may be favoured would be in patients displaying signs of occlusal hypervigilance, with treated TMD or orofacial pain, stable periodontitis and where opposing implants are present.

Number of units placed in supraocclusion

As highlighted above, the Dahl Concept can be readily utilised for single units, exemplified by the Hall technique or the cementation of an adhesive bridge. However, where anterior teeth are involved, it is especially important to ensure that any restoration or prosthesis is designed to direct the forces from the opposing tooth axially to avoid unwanted horizontal movement and changes in inclination.^{42,43}

While there is no specified maximum number of teeth that may be simultaneously placed into supraocclusion, once multiple units are placed in supraocclusion, there is a risk that the untreated teeth will never regain contact, leaving the patient with an increased OVD and an unstable occlusal relationship. A general recommendation of the authors is to restore one sextant per arch at a time and await re-establishment of the occlusion. The authors would not recommend, for example, restoring two posterior sextants in a single arch due to the risk that the anterior teeth would never re-establish, leaving the patient at an increased vertical dimension and an incomplete anterior bite.

Anterior teeth versus posterior teeth

When planning the OVD increase, in addition to aesthetic considerations, it is important to consider both the adequate minimum thickness of material needed to provide structural durability, as well as the relative vertical dimension effect in other parts of the mouth. 'Opening the bite' anteriorly will not open the bite an equal amount posteriorly, and vice versa. Historically, the rule of thumb was



Fig. 10 a) This patient presented with diminutive 12 and congenitally missing 22. b) Crown lengthening surgery to 12 was performed to improve gingival aesthetics. c, d) After tooth whitening, a 22,23 cantilevered adhesive bridge was then placed using the Dahl Concept. The adhesive bridge was ceramic with a nickel-chromium unperforated substructure

1:3;⁴⁴ although, this ratio has been recently disputed.⁴⁵ Potentially, a 1 mm thickness of material added to an incisor will result in a 0.3–0.4 mm opening posteriorly. Whereas 1 mm of material added to a molar will result in a 3 mm opening anteriorly. This has significant implications for the time and predictability of re-establishing anterior contacts when posterior teeth are restored using the Dahl Concept.

We recommend that before undertaking extensive treatment on multiple anterior teeth, when the treatment will significantly alter the aesthetics of the smile, the operator should consider taking the following records for planning and dento-legal purposes:

- Relevant clinical photos
- Relevant radiographs, usually long cone periapicals
- Endodontic sensibility testing of moderately or severely worn teeth
- Study casts mounted in centric relation on a semi-adjustable articulator at an increased occlusal-vertical dimension for a wax-up of the proposed final result. An intraoral scan may be used instead of or in addition to this.

This analogue or digital wax-up can then be transferred to the patient's mouth using a temporary crown and bridge material so the patient can approve the proposed treatment

and the operator can better plan and visualise the final result.

Additional clinical photos can be taken at this stage.

Experienced operators may be able to achieve excellent results using a freehand approach; however, more inexperienced operators will likely be able to obtain more predictable results by using the above clinical approach.

Thus, the Dahl Concept can be used anteriorly and posteriorly, in the author's judgement; however, its use posteriorly (especially on multiple teeth) should be used with greater caution.

Material choice

The authors favour using hard-wearing materials such as type 3 gold and Nickel-Chromium for fixed restorations posteriorly due to their robustness (Fig. 10). The former has shown to have high success rates both when placed using the Dahl Concept and conformatively.⁴⁶ The latter is the material of choice for fabricating predictable adhesive bridges and recognised to also have a high success rate anteriorly and posteriorly.⁴⁷

The authors favour chairside or laboratory-made composite restorations anteriorly. This is due to their combination of low biological cost, cost-effectiveness, high aesthetic finish and chairside reparability. There is also a

relative abundance of data on their medium- to long-term survival in comparison to porcelain and zirconia-based materials. Nevertheless, the authors would consider the use of the latter materials reasonable if the clinician and the patient were aware of the paucity of data on its use.

For fabrication of a removable Dahl appliance, the authors also favour the use of cobalt-chromium, like the original appliance. However, it is important to note that acrylic anterior bite planes have been successfully used by orthodontists to intrude anterior teeth and reduce the overbite for many years. Acrylic prostheses are significantly easier to design, fabricate and are more cost-effective than the alternative appliance.

Thickness of material

Most seasoned clinicians have had the misfortune to place restorations slightly 'high' in the occlusion when attempting to place a conformational restoration. Most patients inevitably adapt and on review describe that the restoration was transiently 'high' or 'proud' in their bite. However, a vocal minority will contact their clinician describing a sore spot on the tooth with symptomatology, like that of an acute apical periodontitis. The symptoms are self-limiting but often, the treating clinician feels obligated to provide one or more appointments for adjustment.

This experience understandably deters some patients from using the Dahl Concept. The authors consider that this occurs when the restoration almost conforms to the patient's occlusion but it is slightly altered, for example, less than 300 microns. This is within the adaptive capacity of the periodontal ligament on some teeth and thus allows the patient to still squeeze the unrestored teeth together. Repetition of this eventually causes a localised occlusal trauma on the offending tooth. This is primary occlusal trauma, or injury resulting in tissue changes from excessive occlusal forces applied to a tooth or teeth with normal periodontal support.³⁸

To prevent the above, the authors recommend that any fixed or removable Dahl appliance is initially placed beyond the adaptive capacity of the periodontal ligament. For example, we would recommend that the restoration/restorations are placed in supraocclusion such that the patient is biting only on these restorations even if the teeth are squeezed together. We consider this of primary importance if using the concept

on one or two teeth only, for example, an adhesive bridge.

Practically, we find that a minimum thickness of restorative material is required of at least 0.7 mm although the authors commonly place material in thickness of 1–2 mm depending on the material type and restored tooth.

Conclusion

The Dahl Concept has a long history of effective use for nearly 50 years. Medium- to long-term data exist on its success, especially in relation to its use in anterior composite rehabilitation for patients with localised anterior tooth wear. Less data exist on its use for the placement of adhesive bridges and the Hall technique.

When used correctly, it preserves tooth tissue, avoids invasive treatment on pathology-free teeth, is potentially reversible and is often repairable chairside.

The authors consider that the most predictable results for using the Dahl Concept occur if the following criteria are met:

- Younger patients
- Anterior teeth
- Class I incisal relationship
- Periodontally healthy and stable
- No TMD/orofacial pain
- No occlusal adaptation issues
- Unrestored dentition
- Little or no root resorption
- No fixed splinting or retention present
- Localised treatment
- Fixed restorations
- Minimum 0.7 mm thickness of material
- Robust or repairable material.

Nonetheless, many patients who do not fit the aforementioned criteria may still be successfully treated using the Dahl Concept, with care. The patient will need to be individually risk-assessed with a thorough discussion of their relative contraindications, which the authors hope will be facilitated by this scientific paper.

The authors can identify few strict contraindications to using the Dahl Concept. A non-exhaustive list is outlined below:

- Unstable periodontitis
- Teeth with stage 3 or 4 periodontitis
- Untreated TMD or orofacial pain
- Teeth with moderate or severe root resorption
- Altered bone metabolism
- Occlusal hypervigilance.

Ethics declaration

The authors declare no conflict of interest.

Author contributions

Arijit Ray-Chaudhuri, Timothy Brown, Emma Ray-Chaudhuri, Raj Dubal, Simon Critchlow, Sara Tabiat-Pour and Kushal Gadhia all contributed equally.

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