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Risk factors and indications of orthodontic temporary anchorage devices: a literature review

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Aims: The aims of this review are twofold, firstly, to give an overview of the general and local risk factors when using temporary anchorage devices (TADs) and the prerequisites for placement and, secondly, to illustrate the orthodontic indications of various TADs.

Methods: The PubMed database was searched for original articles on: 'orthodontics and miniscrews/mini-implants/miniplates/temporary anchorage devices/titanium screws/skeletal anchorage', 'miniscrews/mini-implants/miniplates and risk factors/biomechanics/placement procedure'. Only articles published between 2001 and December 2007 were used. In addition, each article was hand searched for references that may have been missed by the PubMed search.

Results: General risk factors are factors concerning general health. Bone quality and oral hygiene are local risk factors. Aspects of the placement procedure discussed were: primary stability, loading protocols, pre-drilling diameter and whether or not to make an intra-oral incision. A selection of published case reports is given to illustrate some orthodontic indications of TADs.

Conclusions: Temporary anchorage devices have a place in modern orthodontics. Careful treatment planning involving radiographic examination is essential. Consultation with an oral surgeon is advisable if a soft tissue flap is required. Excellent patient compliance, particularly avoidance of inflammation around the implant, is an important consideration for successful use of TADs.

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Introduction

Secure anchorage is a fundamental requirement for successful treatment of many malocclusions. Factors such as inadequate patient compliance may contribute to loss of anchorage, which can be defined as unwanted movement of the anchor teeth and usually occurs when the posterior teeth move forward relative to the anterior teeth. Anchorage can be classified as: Type A or absolute anchorage, i.e. no movement of the anchor teeth occurs; Type B anchorage, i.e. movement of the anterior and posterior units toward each other; Type C anchorage, total loss of anchorage, i.e. the anchor teeth are free to move, usually anteriorly.[1] Intra-oral temporary anchorage devices (TADs) were developed to provide Type A anchorage, because this form of anchorage is difficult to accomplish with conventional biomechanics. Different types of TADs are available with the proponents of each type claiming that their device is superior to other systems. The aim of this review is twofold, firstly, to give an overview of the general and local risk factors when using TADs and the prerequisites for the placement of TADs and, secondly, to illustrate the orthodontic indications of various TADs.

Material and methods

The PubMed database was searched for original articles on 'orthodontics and miniscrews/mini-implants/miniplates/temporary anchorage devices/titanium screws/skeletal anchorage', 'miniscrews/mini-implants/miniplates and risk factors/biomechanics/placement procedure'. Only articles published between 2001 and December 2007 were used. The search retrieved 224 articles. After reading the titles

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and abstracts of all articles, full text versions of 73 articles were obtained for further analysis. In addition, these articles were hand searched for references that may have been missed by PubMed.

Results

General risk factors

Although many of these devices may be placed under local anaesthesia and require minimal surgery, good general health is an important consideration for uneventful healing and avoidance of inflammation around the implant.

Tobacco smoking

Patients who smoke more than 10 cigarettes a day are considered to be 'heavy smokers' and have poor wound healing.[2] A higher failure rate and greater loss of marginal bone around titanium implants occurs in patients who smoke.[3] If dental plaque cannot be controlled, some authors advise cessation of smoking at least one week before and eight weeks after dental implant surgery.[2] Since orthodontists have regular contact with teenagers, one author considers that orthodontists can play an important role in discouraging youngsters from smoking.[4]

Age

Since many TADs are small, temporary devices, they should not influence bone growth. An important age restriction is insertion of a TAD in the palate. Insertion of TADs in the median region of the palate should be delayed until adulthood or at least until the midpalatal suture has calcified. Gracco et al. reported that in patients between 10 and 15 years of age, the thickest palatal bone (between 10.3 and 10.4 mm) was found 4 mm behind and 6 mm lateral to the incisive foramen.[5] In contrast, King and coworkers reported that in adolescents the bone in the paramedian regions of the palate was between 2.1 mm and 7.5 mm thick.[6] They recommended that the thickness of the palatal bone should be determined with a cone beam CT before placing an implant or miniscrew.[6] In their CT study, N'Guyen et al. also reported that the age of complete obliteration of the midpalatal suture in adult males was highly variable.[7] Wehrbein et al. cautioned against use of the term 'suture obliteration' or 'fusion' when a suture is not visible on occlusal radiographs.[8] They reported that in 50 per cent of the subjects with radiological evidence of closure there was no evidence of fusion when the same sutures were examined histologically.[8] In conclusion, care should be exercised when using TADs in the midpalatal region because there may be inadequate bone to support the device. A cone beam CT to determine bone thickness may be justified.

Risk of infective endocarditis

Since placement of orthodontic TADs causes an insult to the oral mucosa and underlying bone, a prophylactic antibiotic has been recommended for patients who are at risk of infective endocarditis.[9]

Diabetes

Placement of TADs and orthodontic treatment should be avoided in patients with poorly controlled insulin-dependent diabetes mellitus, as these individuals are particularly susceptible to periodontal breakdown and have poor wound healing.[10,11] Even in well-controlled diabetics good oral hygiene is essential, since these patients are more prone to gingival inflammation which can cause an implant to fail.[12]

Juvenile idiopathic arthritis

There is no contraindication for the use of orthodontic TADs in patients with juvenile idiopathic arthritis. The clinician should, however, assess whether the wrist joint is affected, since affected patients may find tooth brushing and flossing difficult.[12]

Medication

Any medication likely to hinder wound healing, gingival health and tooth movement should be taken into account prior to placement of a TAD. Examples of medication that may lead to failure of a TAD are: biphosphonates, immunomodulators, anti-epileptics, anti-aggregation medication and anticoagulants.[12]

Local risk factors

Gingivitis and periodontitis

Patients with periodontitis should have their periodontal health improved prior to orthodontic treatment and placement of TADs.[13] Because oral inflammation is one of the major contributing factors to the failure of TADs, it is important to motivate patients with TADs to maintain optimum oral hygiene.[14,15] A single tufted brush to clean the TAD is a useful aid.[16]

Reduced mouth opening

Reduced mouth opening should not be overlooked during the examination. Placement and regular cleaning of TADs and access to orthodontic attachments can be difficult, if not impossible, in a patient with limited mouth opening.[17]

Bone quality

It is not necessary to wait for bone healing and osseointegration to occur because a TAD gains its primary stability from mechanical retention and can support immediate orthodontic loads.[18] The maximum load for a non-integrated implant is proportional to the surface area of the implant in contact with the surrounding bone.[19] Bone 'quality' or density influences primary stability: thick dense, cortical bone provides better mechanical locking for the implant than less dense, cancellous bone.[20]

The mandibular plane angle may influence the thickness of cortical bone and, hence, the stability of TADs. Patients with high mandibular plane angles have significantly thinner buccal cortical bone compared with patients with average or low mandibular plane angles.[21] In a clinical study, Myawaki reported that the failure rate of TADs was correlated with the mandibular plane angle, but other factors, such as screw diameter and peri-implant inflammation, may also contribute to failure.[22] Implants sites should be pre-drilled in areas with dense bone, such as the mandible, the median parts of the upper alveolar ridge and the hard palate.[22]

Radiotherapy

To enhance wound healing in TAD sites in patients receiving radiotherapy, hyperbaric oxygen therapy should be considered. This therapy is only effective on the vascular components of the healing tissue. The cellular components regenerate spontaneously after cessation of radiotherapy.[23]

Placement of implants

Primary stability

An adequate implant placement torque (IPT) is an important factor determining the success rate of TADs inserted in the buccal alveolar bone in the posterior regions of the mandible and the maxilla. Motoyoshi et al. measured the peak IPT with a torquing screwdriver and reported that the success rate of 124 mini-implants in 41 subjects was 85.5 per cent.[24] The mean IPT ranged from 7.2 to 13.5 Ncm and success was related to both the site and the magnitude of the IPT. The IPT for successful mandibular TADs was significantly less than the IPT for unsuccessful mandibular TADs. Therefore, a large IPT is not always an advantage. In this study the IPT for successful 1.6 mm diameter TADs fell within the range 5–10 Ncm.[24] Wilmes et al. reported implants fracture near the implant head when using a cross-driver shaft at torques above 23 Ncm, and recommended that the torque should be generally limited to a maximum of 20 Ncm. A hexagonal head driver may distribute the stresses more evenly on the head of a miniscrew than a screwdriver.[20]

Immediate versus delayed loading

According to Deguchi et al., after a short healing period (maximum 3 weeks) small titanium screws can function as rigid osseous anchorage against orthodontic loads for 3 months.[25] In an experimental study in pigs, Büchter and coworkers determined the clinical and biomechanical outcomes of two different titanium mini-implant systems (102 Abso Anchors, Dentos, Taegu, Korea; 98 Dual Tops, RMO, Denver, Colorado, USA) activated with different load regimens.[19] They reported that loosening of the implants was dependent on the tipping moment at the bone rim, and that a loose implant could only be detected clinically when the load exceeded 90 Ncm. The implants did not move through the bone under the loads they used. A slightly higher torque was needed to remove the Dual Top implants compared with the Abso Anchor implants. Based on the results of this study, immediate loading of mini-implants can be performed without loss of stability providing the tipping moment at the bone rim does not exceed the upper limit of 90 Ncm.[19]

Pilot hole diameter

Wilmes et al. measured the torque required to insert five different mini-implants.[20] The relationship between the diameter of the pilot hole and implant stability can be summarised as follows: the larger the diameter of the pilot hole in relation to the diameter of the implant the lower the primary stability, and the smaller the pilot hole in relation to the implant diameter, the more likely that the implant will fracture. An exception was the 2.0 mm x 10 mm Dual

Table I. List of the case reports illustrating different indications for miniscrews.

Author	Publication year	Type of tooth movement	Number of patients	Manufacturer	Implant positioning
1 Park et al.	2007	Retraction upper anterior elements	1	Orlus, Seoul, (Korea)	2 midplatal, 2 UPM2-M1 buccal
2 Chung et al.	2004	a) En masse retraction max teeth b) Max molar dist	2	C-implants, Seoul, (Korea)	a) Max post site b) UPM2-M1 buccal
3 Gelgör et al.	2004	Retraction upper molars	25	IMF Streiker, Leibinger, (Germany)	3 mm paramedian, 5 mm behind incisive canal
4 Gelgör et al.	2007	Retraction upper molars	40	IMF Streiker, Leibinger, (Germany)	3 mm paramedian, 5 mm behind incisive canal
5 Park et al.	2005	Retraction molars	13	AbsoAnchor Dentos Teagu (Korea)/ Osteomed, Addison (Texas)/Martin, Kalamazoo	4: UPM2-M1 buccal, 2: palat M1-M2, 16: LM2 (distal), 2: Lretromol, 2: LM-M2 buccal
6 Chung et al.	2005	Anchorage for Cl III elastics	1	C-implants, Seoul (Korea)	UPM1-M1
7 Kim et al.	2006	Intrusion maxillary incisors	1	OSAS, Epoch Medical, Seoul (S-Korea)	UI-I
8 Ohnishi	2005	Intrusion maxillary incisors	1	Orthoanchor K1 System; Dentsply, Sankin	UI-I
9 Park et al.	2003	Intrusion max molars	2	?	2 screws palatal M2, 1 miniplate buccal zyg crest
10 Lee et al.	2004	Intrusion max molars	1	Martin, Tuttlingen (Germany)	2: midpalatal M1-M2, 3: buccal M1-M2
11 Jeon et al.	2006	Intrusion max molar (canted occl plane)	1	AVANA Busan (Korea)	2U/LM1-M2, 2U/LPM2-M1 1UPM2-PM1, 1LC-PM1
12 Takano-Yamamoto and Kuroda	2007	Intrusion max molars (canted occl plane)	2	a) Keisei Medical Industrial,Tokyo (Japan) b) AbsoAnchor Dentos, Taegu, (Korea)	a) Zygomatic process b) Buccal UM1-M2
13 Yao et al.	2004	Intrusion maxillary molars	4	Leibinger, Freiburg (Germany)	2: palatal and buccal UM1-M2
16 Freudenthaler et al.	2001	Protraction lower molars	8	Leibinger, Freiburg (Germany)	(Deciduous) LM-PM extraction sites (bicortical)
17 Chung et al.	2007	Retraction upper anterior elements and protraction lower molars	1	C-implants, Seoul (Korea)	UPM2-M1 buccal, LC-PM1
18 Park et al.	2004	Eruption of impacted canines	2	Osteomed, Addison (Texas)	Deciduous canine extraction site
19 Park et al.	2006	Intrusion max/mand posterior teeth	1	Osteomed, Addison (Texas)	U/LM1-M2 + palatal bar/ lingual arch

?, not specified in the article; U, upper jaw; L, lower jaw; M1, first molar; M2, second molar; PM1, first premolar; PM2, second premolar; I, incisor; C, canine

Top screw (RMO, Denver, Colorado, USA), which had the largest diameter (2.0 mm) of the screws tested in relation to diameters of the pilot holes used (largest diameter: 1.3 mm). Because high torque was needed to insert 2.0 mm Dual Top miniscrews into dense compact bone ('compacta') an appropriate diameter of the pilot hole for these miniscrews was 1.3 mm. Smaller pilot hole diameters may result in the miniscrew fracturing.[20] The maximum thickness of compact bone in the mandibular angle is 3 mm. Thus, a pilot hole 3 mm deep will ensure that the compacta will be fully penetrated. In an experimental study in beagles, Kim and coworkers investigated the influence of the drilling procedure (drilling a pilot hole vs. self-tapping) on the stability of the screws under early orthodontic loading. The self-tapping or drill-free screws showed less mobility and more bone-to-metal contact compared with the group that were inserted into a pilot hole (drilling group).[26]

Flap or no flap

Surgery without a soft tissue flap is generally more comfortable for the patient than surgery with a flap.[22] However, a soft tissue flap is necessary when a miniplate is used. A small incision in the mucosa may be necessary to visualise the underlying bone and prevent the mucosa from wrapping around the thread of the screw during insertion.

Orthodontic considerations

In this section we use selected articles to illustrate some of the possibilities of TADs. Although the same biomechanical principles apply to each TAD there are some differences according to the type of TAD. The articles reviewed are summarised in Table I. Orthodontic indications for the use of TADs are only described in case reports. There is a need for more prospective clinical trials with accurate records of the periodontal and orthodontic parameters.

Retraction of upper anterior teeth

Several authors have published case reports using TADs to retract the upper anterior teeth in non-compliant Class II extraction patients. Park described a segmental approach using a palatal appliance connected to two midpalatal mini-implants.[27] He splinted the six anterior teeth palatally. The teeth were retracted 6.1 mm via an extension arm connected to the palatal appliance with elastomeric chain. This approach may have reduced the time the appliance was visible, but it is technique sensitive.[27] Chung combined a segmented approach with a C-implant between the upper second premolar and first molar.[28] The C-implant, a type of mini-implant, has been claimed to gain its stability by osseointegration and mechanical retention. After a healing period of four weeks, the anterior teeth were retracted en masse with elastics from the canine and an extension on the archwire between the upper central and lateral incisors and the head of the mini-implant. Despite the absence of bands and brackets on the posterior teeth during retraction, the posterior teeth moved vertically and mesially. The latter may have, in part, been due to physiologic mesial drift.[28]

Distalisation of molars

Gelgör et al. described upper molar distalisation in 25 adolescent subjects with skeletal Class I and dental Class II malocclusions.[29] In each patient he used a midpalatal screw (IMF Stryker, Leibinger Germany) connected to the distalising appliance, which consisted of a TPA soldered to premolar bands. After a short healing period, NiTi push coils were placed between the premolars and the first molars. No failures were reported by Gelgör et al. who achieved an overcorrected Class I occlusion in 4.6 months. They reported that the upper incisors proclined, the first molars developed a mild distal rotation and the upper premolars rotated mesially, possibly due to the flexibility of the TPA. The miniscrews were removed after distalisation and before the upper incisors were corrected.[29] In a second study, Gelgör et al. compared two different distalising systems based on miniscrews.[30] They used 40 subjects divided into two groups. The first group received the distalising system as described above, and in the second group open coil springs were placed palatally between banded molars and occlusal claws bonded on the premolars. The palatal appliance also included a Nance button around the miniscrew. Both appliances distalised the maxillary molars, but there were more side effects (e.g. rotations, tipping, anchorage loss) in the first group. In group two gingival inflammation under the acrylic plate was a disadvantage.[30] Park investigated distal movement of posterior teeth in 13 patients.[31] He placed 11 microscrews in the mandible and four microscrews in the maxilla. He reported a success rate of 90 per cent: three mandibular microscrews failed. In the upper

jaw microscrews were placed buccally between the second premolar and the first molar or palatally between the first and the second molars. In the lower jaw the microscrews were placed distal to the second molar, in the retromolar area or between the first and second molars. NiTi closed coil springs or elastomeric thread provided the distalising force. The premolars and molars in both jaws were tipped distally, although the first molars tended to move bodily.[31]

Miniscrews can also be used as anchorage for intermaxillary elastics. Chung and coworkers described the treatment of a Class III malocclusion with Class III elastics from the lower appliance to C-implants placed buccally between the upper second premolars and first molars.[32] Force was transmitted to the lower molars with a sliding jig. He reported the lower dentition was successfully distalised with minimal side effects on the upper teeth and mucosa.

Intrusion of anterior teeth

The upper central incisors were successfully intruded in a growing Class II division 2 patient with the aid of a NiTi closed coil spring from a segmented wire to a mini-implant (1.6 x 6.0 mm, OSAS, Epoch Medical, Seoul, South Korea) between the apices of the upper central incisors.[33] The intrusion eliminated the traumatic deep bite and reduced the gummy smile. The upper horizontal section of the box-shaped segmental wire (0.019 x 0.025 inch stainless steel) prevented the NiTi spring from impinging on the oral mucosa. Six months after the start of the treatment the incisors were sufficiently intruded. A twin block with a high-pull headgear and an edgewise appliance were also used. The 1-year post-retention check did not reveal any substantial root resorption using this technique. The desirability of treating a patient only 10.5 years of age and the comfort of this appliance can be questioned. Further treatment may be needed to control any anteroposterior changes. Ohnishi used a miniscrew and a small titanium miniplate or 'abutment' to intrude the upper incisors.[34] The miniscrew was placed in the midline labially and 3 mm above the apices of the upper central incisors. Six months later the abutment was added. A taut steel ligature from the head of the abutment to the upper archwire intruded the upper incisors 4 mm. Over 15 months the incisor roots were also torqued palatally. Treatment for this case took considerably longer than the case reported by Kim.[33] Other clinicians who have used this type of miniscrew did not have a long healing period.

Intrusion of molars

Park and coworkers described two cases with overerupted molars due to extraction of opposing teeth.[35] Because there was insufficient height to place a prosthesis the overerupted molars were intruded with skeletal anchorage. Conventional orthodontic treatment for this type of local malocclusion generally results in extrusion of the anchor teeth. Park used buccal and palatal miniscrews to control the direction of the intrusive force. One should always measure the thickness of the palatal mucosa so that sufficient length of screw is inserted into bone. A buccal miniplate, implanted in the zygomatic crest, is also possible. An intrusive force of 150 to 200 g from elastomeric thread or chain was applied between lingual buttons bonded on the tooth and the miniscrews. During intrusion periapical radiographs should be taken to determine the proximity of the tooth roots to the screw.[35] Lee used a more elaborate appliance with five miniscrews to intrude the upper first and second molars.[36] Two miniscrews were placed in the midpalatal area with an extension arm for four lengths of elastomeric chain to palatal buttons on the molars. Three buccal miniscrews were placed mesial and distal to the extruded molars. Treatment progress was carefully monitored to verify the force system and the bucco-palatal positions of the molars. Lee also used an intrusion force of 150-200 g.[36]

A canted occlusal plane associated with facial asymmetry can also be treated effectively with skeletal anchorage. Jeon et al. described treatment of a Class III patient with facial asymmetry and a canted occlusal plane.[37] The extruded upper molars and premolars were intruded 2.5 mm in 8 months using 3 miniscrews and a transpalatal arch. Three miniscrews were also placed in the mandible on the opposite side and the teeth on that side intruded 1 mm. Correction of the canted occlusal plane with the aid of miniscrews avoided maxillary surgery.[37] The same procedure was used by Takano-Yamamoto and Kuroda to treat two patients with facial asymmetry and canted occlusal planes.[38] In the first patient, the titanium screw was placed in the zygomatic process and the overerupted teeth were intruded 3 mm with a force of 200 g in 6 months. The second younger patient was treated with a combination of titanium screw

anchorage and an intra-oral vertical ramus osteotomy. The screw was placed in the alveolar bone between the first and second molars and the intrusive force applied immediately. The same amount of intrusion was established using this alternative location. In both patients, a transpalatal arch was used to prevent buccal crown tipping.[38]

Yao and coworkers used the same technique as Park et al. for intrusion of maxillary molars, namely, an L-shape miniplate placed buccally and a miniscrew on the palatal slope between the first and second molars.[39] She reported that the palatal cusp of the molar intruded more quickly than the buccal cusps, probably due to the configuration of the molar roots. In five months 3 mm intrusion was achieved with a force of 200 g.[39] In 2005, Yao et al. investigated the envelope of intrusive movements of maxillary molars in cases receiving mini-implants. Of the 22 patients she investigated retrospectively, 18 received a miniplate and a miniscrew and the remainder received buccal and palatal miniscrews. Spatial data on the pretreatment and post-intrusion upper dental casts were recorded with a desktop three-dimensional digitiser. The positional changes in the overerupted upper teeth were superimposed to determine the relocation of specific cusp tips. The upper first molar was intruded, on average, 3 to 4 mm, but there was considerable variation. The intrusion was achieved without significant bucco-palatal tipping.[40]

Protraction of molars

Chung et al. described protraction of the lower second and third molars after the extraction of compromised first molars.[41] Two mini-implants were inserted between the lower canines and first premolars. NiTi closed coil springs were used to apply horizontal forces of 100 g from the implants to extension arms in the auxiliary tubes on the second molar bands. The lower molars were fully protracted (10 mm) in 22 months of treatment.[41] In eight patients, Freudenthaler, Haas and Bantleon reported protraction of the lower molars into the first molar or deciduous second molar extraction spaces with the aid of bicortical titanium screws (Leibinger, Freiburg, Germany).[42] They marked the sites for the titanium screws on the dental casts with foil and transferred the foil marker to each patient. Bone thickness and the prospective positions of the screws were checked with computed tomography. All screws were loaded immediately after insertion with elastomeric chain connected to an extension arm on each molar. A constant force of 150 g was used during active tooth movement.[42]

Forced eruption and correction of posterior buccal crossbite

Miniscrews can also be used as skeletal anchorage for the forced eruption of impacted canines. Radiographs or a cone beam CT should be used to assess the position of the impacted canine to determine if the tooth can be moved into position. Horizontally impacted canines are not good candidates for extrusion with a miniscrew. The miniscrew should be placed in the vestibular alveolar bone close to the alveolar crest to ensure a vertical extrusive force.[43]

To prevent the upper and lower molars from extruding when cross elastics were used to correct a tooth in complete crossbite, Park used two miniscrews: one in the alveolar bone palatal to the upper second molar and the second miniscrew buccal to the lower second molar.[44]

Conclusions

Despite their limitations TADs have a place in orthodontics.

Before placing a TAD, a comprehensive examination and treatment plan are necessary and consultation with an oral surgeon is advisable if a soft tissue flap is required.

Radiographic imaging, often involving cone beam CT, is essential if important structures, such as the roots of adjacent teeth, the inferior dental nerve and the maxillary sinus are to be avoided and bone thickness estimated.

These devices are more likely to be successful if the general and local factors hindering healing, promoting peri-implant infection or reducing the primary stability of an implant are avoided. Continuous patient motivation and oral hygiene instruction with a single tufted brush is desirable.

A prerequisite for retention of a TAD is optimum primary stability, which is related to the bone-implant contact area. This is influenced by the thickness and density of bone, the insertion torque and whether a pilot hole is drilled before an implant is placed. Self-tapping TADs tend to be more secure than TADs placed in a pilot hole.

As a general rule, TADs can be loaded immediately as the primary stability does not depend on osseointegration.

Temporary anchorage devices enable teeth to be moved in non-compliant patients with good oral hygiene and in directions not possible with conventional mechanics. Successful use of a TAD for absolute anchorage depends on good technique and avoidance of inflammation around the implant.

The orthodontic indications for the use of TADs are only described in case reports. There is a need for more prospective clinical trials of these devices.

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