Cracked tooth syndrome – Incidence, clinical findings and treatment

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Abstract

Cracked tooth syndrome (CTS) is a common occurrence in modern general practice. This article reviews the forces placed on the human dentition and the effect restorative dentistry has on the strength of tooth structure. The study reports on the incidence of CTS in a general practice, finding a far higher incidence in teeth which have had the marginal ridge restored than those which have not. The various types of treatment modalities advocated and their relative merits are discussed.

Key words: Cracked tooth syndrome, forces placed on human dentition, restorative dentistry, cusp overlay.

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Introduction

The human dentition is subject to many and varied destructive forces which decrease the longevity of the individual tooth and dentition. The forces placed on the dentition during normal masticatory functions are small when compared with the maximal biting force. Anderson[1,2] measured loads on mandibular molars using strain gauges and found that the maximum whole tooth load varied between 7.2 and 14.9 kg (70.6 and 146 N) when eating meat, biscuit or carrots. De Boever *et al.*[3] reported maximum forces between 2.4 and 7.2 kg (23.5 and 70.6 N) using transmitters in removable pontics, and concluded that functional chewing forces are variable from session to session and change with the consistency and viscosity of the food. In addition, functional chewing forces were small compared with the forces the stomatognathic system can exert. Howell and Manly[4] recorded that the maximum biting force on the first molar was approximately 90 kg (880 N), and Helkimo *et al.*[5] found the maximal biting forces between natural molars ranged from 10-73 kg (98-715 N) with an average of 45.7 kg (448 N) for males and 36.4 kg (357 N) for females. Arnold[6] stated that the ratio of force on molars, premolars and incisors is 4:2:1, with far heavier forces on the most posterior teeth close to muscles producing this force. An individual can generate very high occlusal forces during nocturnal bruxing which can at times be greater than those during conscious effort. This may be due to cortical inhibitors being suppressed during sleeping hours allowing greater forces to be exerted.[7]

'Dental tissues respond biologically to stresses and strains imposed during mastication'.[8] Compromised teeth with restorations ranging from a small occlusal through mesio-occlusal (MO), mesio-occluso-distal (MOD) and endodontically treated teeth become progressively weaker and are prone to further damage. The stresses on these teeth may lead to the formation of microcracks in the dentine and enamel which can propagate, causing symptoms in vital teeth possibly leading to tooth fracture. Preparation of teeth by removal of caries has been shown to significantly reduce tooth rigidity.[8-11] Hood[9] discussed his experimental results on the deflection of cusps in premolar teeth for progressively larger preparations. Total deflection was 11 µm for the intact tooth, 16 µm for minimal occlusal class I cavities, 20 µm for minimal width MO cavities, 24 µm for minimal width MOD cavities and 32.5 µm for extended MOD cavities. After pulpotomy, there was 27.5 µm deformation, with the palatal cusp fracturing after 18 µm deformation under a 10 kg (98 N) load. Pantivisai and Messer[12] loaded mandibular molar teeth at a rate of 20 N/s for 5 s, generating a maximum load of 100 N, and found low cuspal movement of up to 1 µm in intact teeth. In both MO and MOD preparations, small increases in cuspal movement were recorded with conservative and extensive cavity preparation; <2 µm and 3-5 µm respectively. Endodontic access led to a 2-3 fold increase in cuspal movements, which were greatest in the MOD group. When a single cusp was isolated, the resultant cuspal movement was very large at 25-50 µm.

Following class II cavity preparation, the cusps can be considered as behaving like cantilever beams

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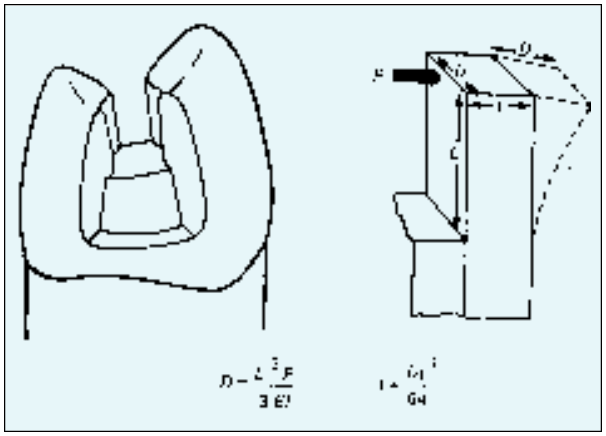

Fig. 1.–Comparison between deflection of simple cantilever beam and cusp of MOD cavity preparation. D=deflection, F=force, E=modulus of elasticity and I=moment of inertia. Beam dimensions are length (L), breadth (b) and thickness (t). From Hood.[9]

(Fig. 1). If, over time, the cusp height doubles as the cavity floor drops, then the deflection will increase by 8 times (because of the L cubed factor). Similarly, if cusp width is reduced by half, deflection will also increase eight times (because of the t cubed factor). When cusps flex under normal functional loading, high stresses are induced at the internal line angles of the cavity, producing microcracks which will propagate and fatigue fracture will eventually occur.

Patients may present with symptoms produced by the crack before the tooth fractures. Cameron in 1964 first used the term 'cracked tooth syndrome' (CTS) to describe this phenomenon, which has been defined as 'an incomplete fracture of a vital posterior tooth involving the dentine and possibly the dental pulp'.[13] Clinical observation of fractured teeth shows that most fractures tend to occur in a direction near parallel to the forces on the cuspal incline (Fig. 2). Hence, with larger restorations, the crack tends to be more superficial and may produce less severe symptoms, or there may be no symptoms at all. This can probably be extrapolated to teeth with smaller restorations and suggests that cracks

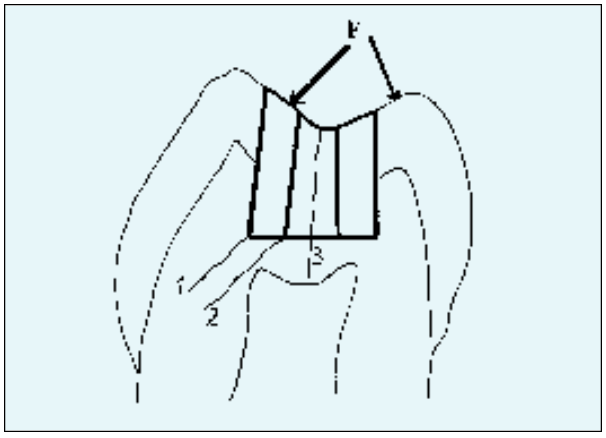

Fig. 2.–Direction of crack propagation in teeth with large restorations (1); small restorations (2); and an unrestored tooth (3); and the direction of forces on the cuspal inclines.

Fig. 3.–(Top). Preparation of an upper premolar with the palatal cusp exhibiting CTS (note amalgam pin or cleat).

Fig. 4.–(Middle). Tooth restored with amalgam.

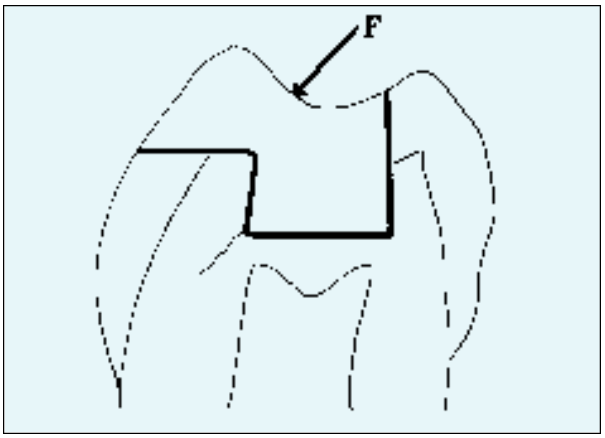

Fig. 5.–(Bottom). Tooth with a large restoration and CTS treated by overlaying the offending cusp with 2 mm of amalgam.

will propagate in a similar direction. The resulting cracks will be much deeper and closer to the pulp and may produce more severe symptoms (Fig. 2). If wedging forces are placed on both buccal and lingual cuspal inclines, the resultant crack may occur in the midline of the tooth and propagate towards the pulp, especially in unrestored teeth (Fig. 2).

Once the diagnosis of CTS is made, treatment should be instituted to alleviate symptoms and secure the safety and longevity of the tooth. If the tooth substance is strong enough, it should be tied

Fig. 6.–Molar protected with orthodontic band and temporary restoration.

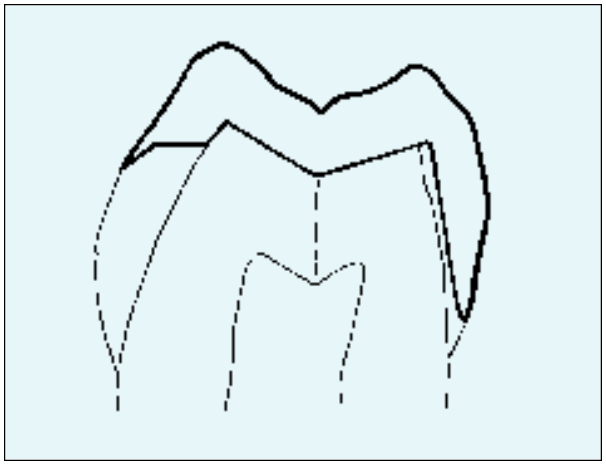

Fig. 7.–(Top). Unrestored tooth with CTS treated by overlaying both cusps with a gold alloy casting.

Fig. 8.–(Bottom). Molar prepared for crown after symptoms have subsided; note crack at mesial margin.

together on either side of the crack to prevent propagation of the crack, microleakage and hydrodynamic pressure in the dentinal tubules.

The most common mode of treatment utilized by the author is the overlaying of the offending cusp with amalgam. The existing restoration is removed and light pressure is placed on the cracked cusp. If it is too weak, it will fracture at the site of the crack and can be restored in a conventional manner. If it resists this pressure, the cracked cusp is reduced by 2 mm (for adequate bulk of amalgam), with a small amalgam pin or cleat for retention (Fig. 3) to tie the two sides of the crack together, and overlaid with amalgam (Fig. 4, 5). This protects the cusp from further loading and prevents crack propagation. Hood[9] found that 'teeth restored with amalgam overlays had fracture energies equal to those of intact teeth'. Gold and porcelain inlays may also be used in a similar way to tie the cusps together. Widdop[14] described the use of cross-pinning, where pins are placed on either side of the crack and the restorative material is packed around these, effectively binding the tooth structure together either side of the crack. However, if the cusp is left unprotected, there is probably enough movement to allow microleakage and a continuation of symptoms.

Some clinicians recommend the use of a reinforced glass ionomer cement (GIC) or bonded resin composite to hold the cusps together. The bond strength of the GIC to hard tissue is inadequate to withstand the forces to which the tooth is subjected.[9] Bonded resin composite restorations have been shown to strengthen a tooth after cavity preparation. However, this is much less in an extensive restoration than in a minimal restoration;[15] it is 'extremely variable even under the optimal conditions prevailing in a laboratory study',[9] and it did not increase the fracture resistance.[9] If the cusps are subject to continual forces, fatigue failure of the bond will be progressive with time,[9] which is of little help with CTS. Ehrmann and Tyas[13] suggested the use of a stainless steel orthodontic band which is cemented around the cracked tooth, binding the cusps together (Fig. 6). This has the advantage of allowing time to see if the symptoms are reversible. The patient is told to use the tooth normally, and if after review in 2-4 weeks the symptoms have subsided, the tooth can be restored more confidently with an overlay restoration.

The author utilizes the first and last methods most commonly in his practice. In the heavily restored tooth where CTS often occurs and the crack is most likely to be superficial, the offending cusp is diagnosed and then overlaid with amalgam (Fig. 5). However, in the less commonly occurring CTS, in a minimally restored or unrestored tooth, the crack is likely to be deeper, the symptoms more severe, and the long-term prognosis more catastrophic if the crack is left to continue to propagate. Here an orthodontic band is cemented and a temporary restoration placed (usually zinc oxide-eugenol based), and left for at least four weeks to see if the symptoms subside. If they do, the tooth is restored by overlaying both buccal and lingual cusps, normally with a cast restoration (Fig. 7, 8), since teeth restored with metal overlays or crowns have fracture energies greater than three times those of intact teeth.[9] If the symptoms do not subside

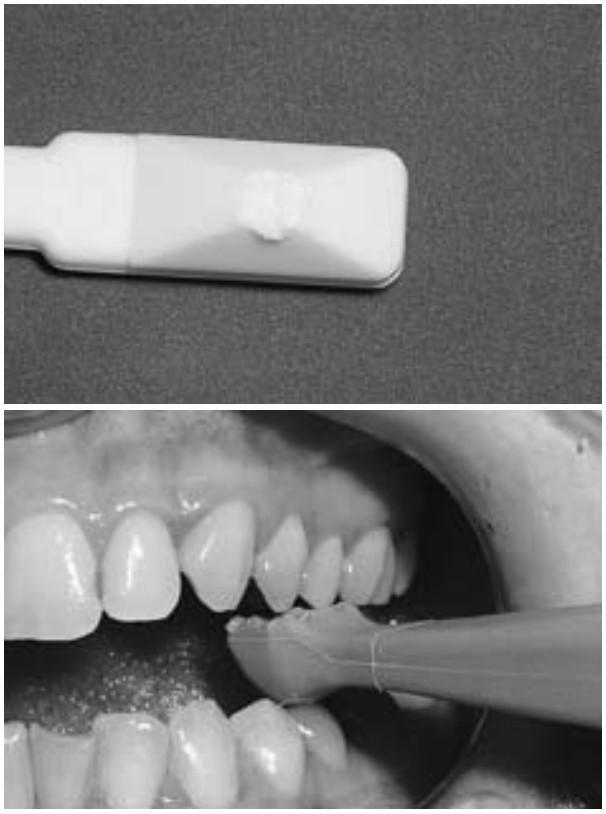

Fig. 9.–Tooth Slooth. a, b, Clinical photograph of the use of a Fracfinder identifying the offending cusp.

endodontic therapy or even extraction may be required.

The most commonly affected teeth are the mandibular molars, for example, as reported by Cameron[16] (67 per cent) and Hiatt[17] (69 per cent). Mandibular second molars were more likely to be involved than first molars. Cameron[16] found that 'most posterior teeth that crack have been restored' and also 'there was a direct relationship between the size of the restorations and the number of teeth cracked'. She found in a series of 102 teeth that 27.5 per cent had occlusal restorations, 33.3 per cent had MO or DO restorations, 32.4 per cent had MOD restorations, and 6.8 per cent had other or no restorations. Hiatt,[17] however, found 35 per cent of cases occurred in teeth without restorations and 39 per cent occurred in teeth with class I occlusal restorations. In only 26 per cent of cases was there a class II restoration. Unfortunately, since a key sign for inclusion in this study[17] was a proximal hairline fracture which had been stained, many teeth with both marginal ridges restored were excluded. Ehrmann,[13] more recently, has stated that 'the majority of cases occur on unrestored teeth or in teeth with only class I restorations and which are completely free of caries'.

Cracked tooth syndrome is often diagnosed by a very detailed history of the complaint. The patient will give a history of pain on biting on a particular tooth, often occurring with foods that have small, discrete, harder particles in them, for example, bread with hard seeds or muesli. Patients may also complain of sensitivity to cold, sweet or hot, depending on how far the crack has propagated into the tooth. Intraorally a Tooth Slooth† or a Fracfinder‡ (Fig. 9a) can be used on each individual cusp and the patient asked to bite, thus allowing the placement of selective pressure on one cusp. If there is pain on biting or release of biting pressure, it is indicative that this cusp is cracked (Fig. 9b). The crack may be visible in the enamel at the marginal ridge or propagating from the external line angle of the restoration. Removal of the restoration may show the extent of the crack in a mesio-distal or a bucco-lingual (less common) direction, but will not give an indication of its apical direction. If the crack is at a very early stage it may not be visible to the naked eye. Dewberry[18] has suggested that cracks 'often can hardly be seen with the naked eye' and Ehrmann[13] stated 'at the early stage the crack lines are often tiny and not easily seen even with a magnifying loupe'. Dewberry[18] suggested the use of magnifying lenses with transilluminating light in a darkened room. Cameron[16] described the use of a dye, for example, methylene blue, which can be sealed into the cavity with a zinc oxide-eugenol dressing. Maloney (personal communication, December 1993) described the use of Ledermix paste§ in a similar manner. The use of rubber dam enhances the probability of visualizing these cracks, by isolating the tooth with a contrasting colour, keeping the area free of saliva and removing peripheral distractions.

The aim of the study reported here was to examine the incidence, clinical signs and symptoms, and treatment of consecutive cases of CTS in a general practice. The advantage of a study using consecutive cases is that it will give a more accurate reflection of incidence than a study which uses random cases.

Materials and method

Sixty-two consecutive teeth which exhibited signs and symptoms of CTS were examined over a 15-month period and various data were documented. These teeth gave a history indicating CTS and in almost all cases the symptom of pain on biting could be reproduced with the use of a Tooth Slooth or Fracfinder on the offending cusp. The data recorded (Table 1) included the symptoms of tenderness to biting and sensitivity to cold and/or hot, to sweet, the restoration present (surfaces involved), if occlusal wear facets were present, whether the crack was visible, and how the tooth was finally restored.

Once a diagnosis of CTS was made, the relevant arch was isolated with rubber dam and the existing restoration removed. The cavity preparation was

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‡SDI, Upplands Vasby, Sweden.
§Lederle Pharmaceuticals, Wolfrathausen, Germany.

Table 1. Summary of recorded data from study of CTS in a general practice

	No. of teeth	%
Teeth with CTS	62	100
Tender to bite	56	90
Pain on cold/sweet/hot stimulation	30	48
Restoration present		
Occlusal	15	24
Mesio- or disto-occlusal	23	37
Mesio-occluso-distal	24	39
Occlusal wear facets	52	84
Crack visible	56	95
	(3 not recorded)	
Treatment		
Cusp overlay – amalgam	48	77
– composite	3	5
Orthodontic band and sedative dressing	8	13
Crown	2	3
Extraction	1	2

examined carefully for evidence of a crack, especially at the base of the cusp exhibiting symptoms. The offending cusp was normally overlaid with amalgam or much less commonly with resin composite if aesthetics demanded. Alternatively, an orthodontic band was placed if there was a midline crack or if the symptoms indicated an irreversible pulpal state (that is, 'C' fibre stimulation).

Results (Table 1)

Of the 62 teeth with CTS, 63 per cent (39 teeth) were found in women and 37 per cent (23 teeth) in men. When these patients presented, 90 per cent (56 teeth) had symptoms of tenderness when biting, particularly on grainy or tough foods, and 48 per cent (30 teeth) described tenderness to cold, hot or sweet or a combination of these (Table 1). In the analysis of existing restorations in the teeth exhibiting CTS, this series found no unrestored teeth (although the author has experienced this in the past), 24 per cent (15 teeth) had existing occlusal restorations, 37 per cent (23 teeth) had existing MO or DO restorations, and 39 per cent (24 teeth) had existing mesio-occlusal-distal restorations. Of the teeth with CTS, it was observed that 84 per cent (52 teeth) had evidence of occlusal wear on the affected tooth and in 95 per cent of cases (56 teeth) the crack was visible after the existing restoration was removed.

Treatment of these teeth most commonly involved overlaying the cracked cusp in amalgam (77 per cent; 48 teeth), or composite resin (5 per cent; 3 teeth), after first reducing the cusp height by 2 mm. Orthodontic bands were placed in 13 per cent of cases (8 teeth) where it was felt the pulpal status was in jeopardy; that is, where symptoms indicated deeper pulpal injury with stimulation of C fibres (reaction to heat or a lasting dull ache), or where it was felt that with any further propagation of the crack it may enter the pulp chamber (teeth with minimal occlusal restorations). Two upper premolar teeth (3 per cent) were restored with crowns at the patient's request for aesthetic reasons, and one tooth (1 per cent) – an upper premolar with a minimal MO gold inlay – had to be extracted a week or so after diagnosis of CTS as the root was split.

Three of the teeth which had been overlaid with amalgam had continuing symptoms or symptoms which returned and these were treated with orthodontic banding until the symptoms disappeared and then protected with full coverage castings (gold or porcelain bonded to gold). In two of the teeth which had orthodontic bands placed initially, the symptoms returned and became progressively worse requiring endodontic treatment, and in one tooth the pulp was extirpated at the time of band placement.

Discussion

In this study, 62 consecutive cases of CTS were analysed, whereas Cameron[16] studied 102 random teeth over 10 years and Snyder[19] carried out a retrospective study from past appointment records and patient records including cusps already fractured. Hiatt[17] analysed 100 teeth with no indication of whether or not they were consecutive cases, and only included teeth with a proximal vertical hairline fracture on an unrestored marginal ridge. This, therefore, excluded many teeth with both marginal ridges restored even though they responded to chewing pressure on a burlew wheel (that is, exhibited symptoms typical of CTS). Ehrmann[13] seems to have based his statement that 'the majority of cases occur on unrestored teeth or in teeth with only class I restorations and which are completely free of caries' on Hiatt's study.[17] However, as a specialist endodontist, Ehrmann[13] would see a skewed sample of those difficult or obscure cases unable to be diagnosed by a general practitioner and hence would not see a typical cross-section of patients as seen in general practice.

The present study provides information which relates to, and is more relevant to, a general practice environment. The ratio of female to male of approximately 2:1 was similar to that found by Cameron,[16] (67 per cent to 33 per cent); however, this may reflect the higher number of female patients seen or a lesser tendency of male patients to report symptoms. The low percentage (24 per cent) of teeth with CTS having only class I restorations which had not significantly weakened the tooth is similar to Cameron's 34 per cent,[16] but differs markedly when compared to Hiatt's 74 per cent.[17] However, Hiatt's[17] figure is not a true reflection of the incidence of CTS because of his selection criteria. The higher percentage of teeth involved with CTS that had one or both marginal ridges restored (76 per cent), indicated that weakening of the tooth by loss of the marginal ridge made the tooth more susceptible to CTS.

When discussing the symptoms of these patients, most (90 per cent) described tenderness to biting,

especially grainy or tough foods, with the pain being short and sharp. Fewer (48 per cent) described a reaction to cold, sweet or hot or a combination of these, with cold being the most common, then sweet. These symptoms can be explained by the hydrodynamic theory of pain first described by Gysi,[20] and since substantiated experimentally by Brännström.[21] This theory is based on the concept that rapid movement of dentinal fluid in the dentinal tubules causes pain. This movement stimulates mechano-receptors in close proximity to the odontoblast cell body, which then activate A-delta nerve fibres (faster myelinated fibres), resulting in a short sharp pain. The pain is produced with movement of dentinal fluid when the crack is opened by pressure on the cusp, and it also explains the short sharp pain as the fluid moves back on releasing the pressure. Seventy to eighty per cent of nerve fibres entering the pulp are non-myelinated fibres, known as C-fibres. These fibres are slow-conducting and produce a dull, poorly localized sensation and are activated by inflammation, heat and mechanical deformation. The pain is a dull, poorly localized ache which increases after a hot drink. These fibres are usually activated by stimuli which cause actual damage to the pulp.[20] If a tooth with CTS is exhibiting this type of pain, urgent treatment is required to tie the cusps together (for example, an orthodontic band) and a sedative dressing is required (ZOE to seal the cavity and hopefully maintain the vitality of the pulp).

A few authors have discussed difficulties in identifying the cracks; however, with the use of rubber dam in this study to provide a dry field, a contrasting colour and minimized peripheral distractions, only 5 per cent of cracks could not be identified.

Conclusions

1. Cracked tooth syndrome is a relatively common occurrence in general practice, occurring approximately once per week on average per full-time practitioner.

2. Cracked tooth syndrome is likely to occur three times more commonly in a tooth which has been weakened by restoration of one or both marginal ridges, than a tooth which only has an occlusal restoration.

3. If a tooth exhibiting cracked tooth syndrome has no (or a minimal) occlusal restoration, or it has symptoms to hot or lingering pain indicative of C-fibre stimulation, a sedative dressing and an orthodontic band should be placed to prevent crack propagation, hopefully maintaining pulp vitality, and a waiting time of at least one month after the symptoms subside should be undertaken before protecting the tooth with a casting.

4. In most cases (except those in 3 above) the tooth can be successfully restored by overlaying the cusp with amalgam or resin composite; however, the patient should always be warned of the possibility of the tooth requiring further treatment.

5. Conservation of tooth structure in cavity preparations is important in the prevention of CTS.

6. Almost all cracks can be identified after isolation with rubber dam.

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