The role of piezosurgery in implant dentistry

Adam Patel details the huge potential of piezosurgery for improving the predictability and ease of dental implant treatment

CPD

Aims and objectives

This article aims to demonstrate the benefits and drawbacks of piezosurgery across a range of applications within implant dentistry.

Readers will:

- Learn
- See
- Understand.

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Piezosurgery was first introduced in 1988. Its development was encouraged by the need for high levels of precision and safety in bone surgery compared with that achieved by standard bur and saw instruments (Landes et al, 2008).

Piezosurgery as a technique spread because of its ease of use and safety. The piezoelectric effect occurs when an electric current is passed around a stack of crystals and they start to vibrate at a precise frequency. The piezoelectric instrument produces a modulated ultrasonic frequency of 24 to 29 kHz, and a microvibration amplitude between 60 and 200 mm/sec (Sortino et al, 2008). The amplitude of these microvibrations allows a clean, precise and controlled cut of bony structures without causing destruction of soft tissue (including nerves, blood vessels and oral mucosa) (Eggers et al, 2004).

Since its introduction, piezosurgery has established an important role in various aspects of dentistry and dental implantology (see the box: Uses of piezosurgery in dental implantology).

This article will discuss the role of piezosurgery in these areas, including its advantages and disadvantages.

Properties and characteristics

The piezosurgery unit provides three different power levels (endo, perio and cortical/spongious), the highest of which is used in bone surgery. The amplitude of the working tip ranges from 60 to 200m/sec, with variable ultrasonic frequencies (Beziat et al, 2007).

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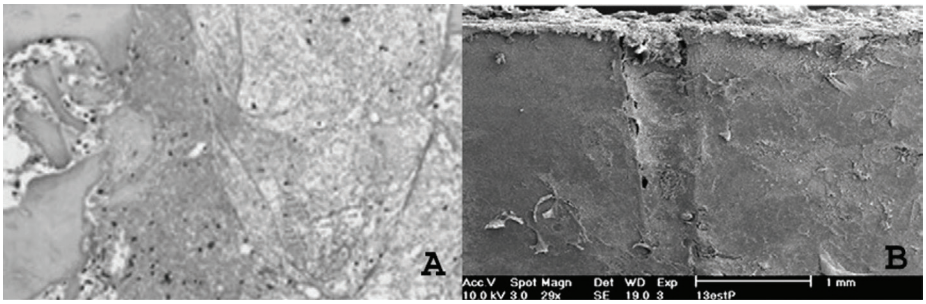


Figure 1: Microscopic examination of bone fragments acquired during piezosurgery shows viable cells on bony surfaces with no signs of coagulative necrosis

A distinctive characteristic of piezosurgery is its ability to distinguish tissue hardness. It will act only on mineralised structures and thus will not cut or damage soft tissues. This occurs due to cessation of the surgical action when the scalpel comes into contact with demineralised structures (Robiony et al, 2007).

Piezosurgery can be advantageous when exact cutting of thin bones is required. The modulated ultrasonic vibrations allow controlled cutting of bony structures. Delicate bony structures can be cut easily and with great precision. However, it is only of limited use in cutting highly dense bone and in regions with limited access (Eggers et al, 2004).

Because of its micrometric and selective cut, the piezosurgery unit produces safe and precise osteotomies without any osteonecrotic damage (Robiony et al, 2004).

Due to its cavitational effect on physiological solutions such as blood, piezosurgery creates an effectively bloodless surgical site that makes visibility in the working area much clearer than with conventional bone cutting instruments (González-García, 2007).

The digital modulation of the oscillation frequencies and the high-flow irrigation system of the piezosurgery unit minimises overheating of the bone during osteotomies (Robiony et al, 2007). Unlike conventional burs and micro saws, piezosurgery inserts do not become hot either, which again reduces the risk of postoperative necrosis and helps maintain vitality of adjacent tissue (Horton et al, 1975).

In comparison with traditional rotary instrumentation, piezosurgery requires much less hand pressure. This leads to enhanced operator sensitivity and control, allowing the clinician to develop a better 'feel' and precision for the cutting action because of the microvibration of the cutting tip (Seshan et al, 2009).

Osseous response

Microscopic examination of bone fragments acquired during piezosurgery (Figure 1) have shown viable cells on the bony surfaces with no signs of coagulative necrosis (Robiony et al, 2007).

Research has shown a more favourable osseous response, with less bone damage when compared with diamond or carbide burs (Vercellotti et al, 2005).

A study by Preti et al (2007) concluded that piezoelectric bone surgery is more effective in stimulating implant osteogenesis, promoting more osteoblastic activity around the implant sites compared to sites prepared conventionally with drills.

Another study comparing piezosurgery with carbide and diamond burs to cut experimental osteotomies showed conventionally treated surgical sites lost bone level by day 14, compared to those treated by piezosurgery – which actually gained bone level. The study concluded that piezosurgery provides more favourable osseous repair and remodelling compared to burs when

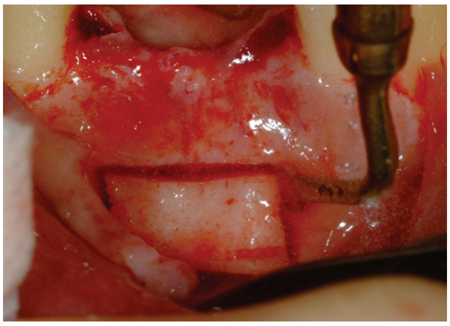
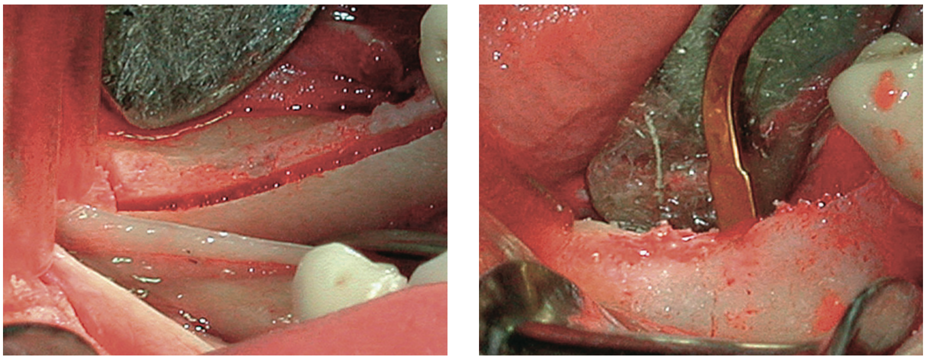


Figure 2: Chin block graft being harvested from the anterior mandible



Figures 3a and 3b: Ridge expansion is the surgical widening of a bone ridge in the mouth to allow for the placement of dental implants

surgical ostectomy and osteoplasty procedures were performed (Landes et al, 2008).

A study examined the recovery process of dogs that had gone through osteotomies with various techniques. In this study, the clinical and histological aspects of three surgery techniques: scalpel, piezosurgery and low-speed bur were analysed. The recovery process after scalpel and piezosurgery were similar. However, a difference was observed in the recovery of bone tissue treated by a bur, as it produced degeneration of cellular elements along the edges, persistence of fibrovascular tissue, and a reduced reaction of osteoblasts and osteoclasts (Sortino et al, 2008).

Healing

By applying the same surgery protocol and measurement methods, the study also compared rotary and piezosurgery with regards to time taken to complete surgery and postoperative healing. The average time of surgery was 25.83% higher in the piezosurgery group compared with rotary. The facial swelling and trismus at 24 hours post surgery with piezosurgery were respectively 40.06% and 25.3% lower compared with rotatory osteotomy technique. The results of the comparative study showed that piezosurgery reduces the postoperative facial swelling and trismus, although increases the time of surgery (Sortino et al, 2008).

Disadvantages

One key disadvantage of piezosurgery is the time involved: the piezoelectric scalpel requires repeated application to the bone to progressively deepen the cut and complete the osteotomy.

This increased preparation time inevitably carries financial implications, so slightly higher costs may be involved.

Piezosurgery usage in areas of highly dense cortical bone may have limited cutting strength and may not function as effectively as burs, and thus may not be suitable for all implant site preparations.

Bone grafting

There is a range of techniques available to manage deficient alveolar ridges. These include:

- Block bone grafting
- Guided bone regeneration
- Distraction osteogenesis
- Ridge expansion.

Block bone grafting

The correct positioning of implants, in accordance with prosthodontic and functional principles, can be compromised by bone volume or density.

The aim of augmentation is to reconstitute the original hard tissue contours as far as possible (Gellrich et al, 2007). Atrophic alveolar ridges should be restored by bone augmentation so as to allow optimal implant positioning within the prosthetic envelope (Muñoz-Guerra et al, 2009).

Various resources for bone grafting exist, including the use of allografts, xenografts and alloplastic materials. However, autologous bone is still regarded as the gold standard with respect to intended bone quantity, quality, and an uneventful healing phase with reliable outcome (Gellrich et al 2007).

Piezosurgery can be used effectively in autogenous block bone grafting procedures.

Autogenous grafts can be harvested from both intra and extraoral sites. The most common intraoral sites include the mandibular ramus and symphysis, where delicate structures exist. One of the most significant advantages of piezosurgery over conventional burs and saws is its selective cut. This means that bone can be cut with relative ease while soft tissue, including nerves, blood vessels and mucosal tissues remain unharmed, even if they come into direct contact with the cutting tip (Stübinger et al, 2006).

In comparison with surgical burs and microsaws, piezosurgery requires only a feather-light touch allowing better operator sensitivity and control. As a result the clinician develops a better feel and precision for the cutting action, can feel the transition from cortical to cancellous bone and produces precise and clean cuts up to one centimetre deep. Consequently, the operator minimises trauma and wastage to the adjacent bone, creating grafts of optimum dimensions.

Figure 2 demonstrates a chin block graft being harvested from the anterior mandible.

Because piezosurgery does not traumatise the bone, it prevents the considerable bone necrosis often caused by surgical burs and microsaws (Vercellotti and Pollack, 2006). Histological research has shown a clear lack of postoperative cellular damage to the resection edges, bony matrix or bone marrow.

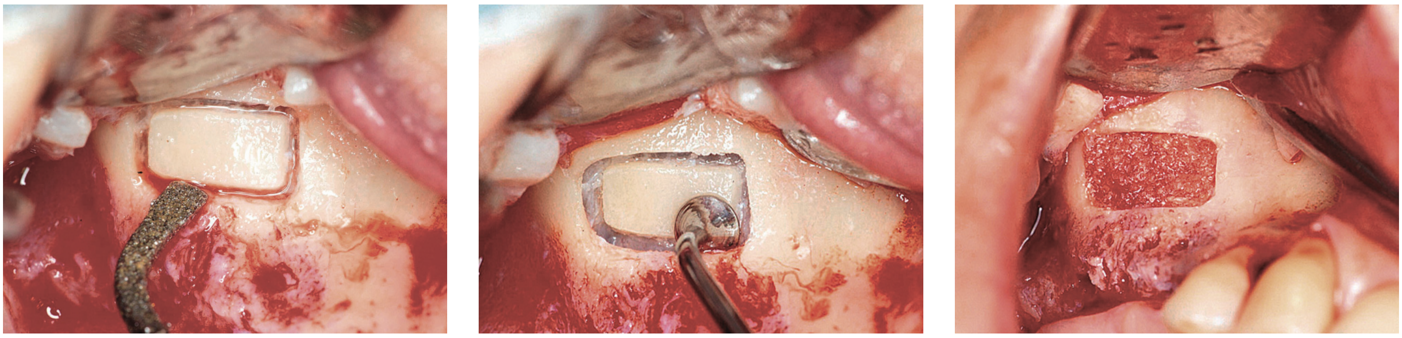
There is also evidence of the presence of vital osteoblasts near the cut section of bone – meaning that bone cut with piezosurgery stays vital, and any bone chips that are harvested will contain vital osteoblasts as well as bone matrix, which, in turn, will increase healing rate.

In addition, less periosteal stripping occurs when using piezosurgery so there is subsequently less postoperative pain and swelling, and wound healing is improved (Landes et al, 2008). The risk of postoperative necrosis is further reduced because piezosurgery inserts do not get hot (Vercellotti and Pollack, 2006).

The overall patient experience may be less traumatic, with reduced donor and recipient site morbidity – and fewer complaints about vibration compared to with conventional burs and microsaws.

Guided bone regeneration

Piezosurgery is also very useful for harvesting bone chips, which are produced at the optimum grain size for effectiveness and remain on the bone surface ready for collection. Two surgical tips are available for removal of cortical bone, eliminating the need for bone traps. These bone chips can be used alone or in combination with other graft material for guided bone



Figures 4a, 4b and 4c: Lateral sinus window cut using piezosurgery followed by gradual lifting of the Schneiderian membrane and subsequent particulate sinus grafting

regeneration purposes.

Landes et al (2008) assessed bone chips collected using piezosurgery and conventional burs and found no difference in the detrimental effect on the viability and differentiation of cells, but found piezosurgery was more economical in regard to quantity of bone harvested.

Distraction osteogenesis

Distraction osteogenesis is a method of regaining both hard and soft tissue without grafting. It is the biological process of new bone formation through the application of graduated tensile stress by incremental traction.

With ridges that require four to five millimetres of vertical height augmentation, or where the overlying soft tissue does not support osseous augmentation, distraction osteogenesis is a useful treatment alternative, with piezosurgery being an effective tool for distraction osteotomies (Lee et al, 2007).

When performing distraction osteogenesis in certain areas it is critical to complete the osteotomies delicately, because they are performed close to dental and periodontal structures, and to soft tissues that provide vascularisation.

The advantage is that we can osteotomise as precisely as possible due to its micrometric and linear vibrations, and cause minimal damage to hard and soft tissues (Vercellotti, 2000).

The use of piezosurgery can permit ideal osteotomy preparation without flap damage, providing abundant vascularisation that leads to successful new bone formation. Furthermore, it is possible to get direct visibility over entire osteotomies. The only minor limitation is the slightly longer time required for the operation.

Ridge expansion

Ridge expansion is the surgical widening of a bone ridge in the mouth to allow for the placement of dental implants (Figure 3). It can allow for a shortened treatment time and eliminates the issue of donor-site morbidity, as grafting is not required.

Piezosurgery was originally designed for augmentation in implant surgery, including sinus lifts and procedures such as ridge expansion (Eggers et al, 2004). It can be used to cut the crestal and proximal facial cortices in a precise and tactile controlled manner. Motorised osteotomes are then used to widen the split ridge and create space.

This technique allows for the expansion of narrow, anatomically limiting, atrophic ridges, creating space for immediate placement of implants.

The facial and lingual cortices provide necessary support with vital osteocytes for osteogenesis (Kelly and Flanagan, 2013).

Sinus lifts

Atrophy of the maxilla and progressive pneumatisation of the maxillary sinus can compromise implant placement in the posterior maxilla

Atrophy can lead to inadequate height, width, and quality of bone restricting ideal implant positioning and risking perforation of the sinus floor (Muñoz-Guerra et al, 2009). There can often be as little as a few millimetres of bone between sinus and the oral cavity.

Piezosurgery can be used as an alternative or adjunct to standard instrumentation during a sinus lift procedure (Figure 4).

The sinus is accessed through a window prepared in the lateral wall of the sinus, conventionally made using a diamond bur and then infracturing of the bony window.

However, a round piezosurgery tip may be used to prepare the window instead, which brings the advantage of being able to touch the sinus lining without tearing it. This eliminates the need to leave a thin layer of bone around the window and tap it in (and thus further reduces the chance of perforation).

A blunt inverted cone tip can then be used to raise the sinus lining, reducing the risk of damage to the membrane even further.

In cases of sinus lift, studies have shown it can reduce the membrane perforation rate from 30% with the conventional approach to 7% with the piezosurgery (Wallace et al, 2007).

Le Fort I osteotomies

In severely atrophic alveolar ridges, both the maxilla and mandible can present a jaw discrepancy, with a skeletal Class III tendency and a loss of vertical dimension that may hinder treatment with dental implants (Muñoz-Guerra, et al 2009).

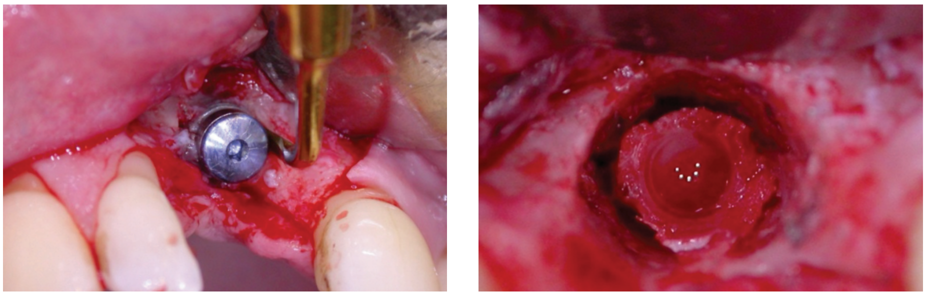
Severe atrophy of the edentulous maxilla can cause insufficient bone volume and an unfavourable vertical, transverse, and sagittal relationship, due to the tri-dimensional resorption pattern of long-term maxillary edentulism (Muñoz-Guerra et al, 2009).

Maxillary sinus augmentation and onlay grafting procedures can allow the correction of bone defects, but are often insufficient to correct severe maxillary retrusion and increased inter-arch distance. Le Fort I osteotomies allow for forward or downward repositioning of the maxilla, to correct inter-maxillary vertical and transverse discrepancies (Bell et al, 1977).

Correction of osseous deficiencies using this technique permits ideal implant placement, and creates a more natural soft tissue profile that impacts on the overall prosthodontic outcome.

The precise nature of piezosurgery provides exact, clean, and smooth cut geometries (Stübinger et al, 2005). This is an extremely important attribute considering an atrophic maxilla is likely to present with a thin and fragile bone structure that may increase the risk of accidental fracture.

The application of piezosurgery in these instances is advocated over other mechanical instruments because it minimises the chances of accidental damage (Muñoz-Guerra et al, 2009). The risk to critical anatomical structures, such as the palatine nerve and artery, is also minimised because the surgical action stops when the piezosurgery insert comes into contact with



Figures 5a and 5b: Introduction of the piezosurgery tip (5a) and implant site post explantation (5b)

USES OF PIEZOSURGERY IN IMPLANT DENTISTRY

- Bone grafting procedures
- Bone harvesting (chips)
- Distraction osteogenesis
- Ridge expansion
- Sinus lifts
- Le Fort I osteotomies
- Surgically assisted rapid maxillary expansion (SARME)
- Implant site preparation
- Relocation of a malpositioned implant
- Nerve transpositions
- Atraumatic tooth extraction
- Peri-mucositis/peri-implantitis and calculus removal.

demineralised structures (Robiony et al, 2007).

However, it must be noted that the success rate of implants placed in a reconstructed maxillae following a Le Fort I technique and bone grafting is significantly lower than that of implants placed in an edentulous but non-reconstructed maxillae (Chiapasco et al, 2007).

Piezosurgery has also been used in various other craniofacial surgical procedures in addition to Le Fort osteotomies, including calvarian bone grafting and mandibular sagittal splits (Beziat et al, 2007).

Surgically-assisted rapid maxillary expansion (SARME)

Surgically-assisted rapid maxillary expansion (SARME) is another well established procedure to correct maxillary transverse discrepancies. Piezosurgery can be used to carry out the surgical aspect of this technique and carries the same surgical advantages as those mentioned previously within this article.

Implant site preparation

Piezosurgery is efficient at preparing implant site osteotomies due to its selective cut, micro-streaming and cavitational effects, which preserve and maintain the soft tissue – essential for the overall healing and aesthetics of the implant (Sortino et al, 2008).

Micro-streaming is the continuous whirling movement of fluid created by a vibrating insert that favours a mechanical action of debris removal. Intraoperative visibility is enhanced with piezosurgery by the implosion of gas bullae into blood vessels during the osteotomy, which have a haemostatic effect – the cavitational phenomenon (Sortino et al, 2008).

Primary implant stability and osseointegration are directly indicative of implant prognosis. Primary implant stability can provide an early indication of future osseointegration.

A recent study by Baker et al (2012) has suggested that there are no statistically significant differences between primary implant stability provided by using the piezosurgery in comparison with a conventional rotary unit. However, due to the study being ex vivo in nature and the relatively small sample size, further studies are recommended.

In a minipig model, bone healing at intervals of one, two, four and eight weeks in sites prepared with piezosurgery was compared to sites prepared with conventional drills. The study (Preti et al, 2007) concluded that piezosurgery was more effective in stimulating implant osteogenesis, promoting more osteoblastic activity around the implant sites compared to sites prepared conventionally with drills.

Another randomised control trial suggested that piezosurgery implant site preparation 'has the potential to modify biological events during the osseointegration process, resulting in a limited decrease of implant stability quotient values and in an earlier shifting from a decreasing to an increasing stability pattern' in comparison with traditional drilling technique (Stacchi et al, 2013).

Relocation of malpositioned implants

Implant relocation (Figure 5) is a relatively new surgical technique used to move integrated implants along with their surrounding bone into a more desired position.

Inadequately positioned implants can either be left as 'sleeper' implants, if their support is not essential for rehabilitation, or surgically removed and then replaced. The disadvantage of surgically removing the implant is that bony defects may be created, which compromise the ideal placement of another implant.

Another option is to surgically remove the implant with its surrounding bone into a more appropriate position. This peri-implant osteotomy can be accomplished by using conventional burs, saws or piezosurgery (Stacchi et al, 2008).

The advantage of using piezosurgery for this procedure is that maximum intra-operative control can be maintained to ensure a precise cut and minimal bone ablation. In addition, the healing response is likely to be more favourable in comparison to cuts using burs or saws (Preti et al, 2007).

Nerve transpositions

Piezosurgery can be used for nerve lateralisation or transposition procedures.

The precise and selective surgical cut of piezosurgery is extremely important when performing surgery close to nerves such as the inferior alveolar nerve. Eriksson et al (2006) reported that an interruption of the structures of a nerve would result in proliferation of axons, a patho-physiological cause of paraesthesia and dysaesthesia.

An in vitro study compared piezosurgery with conventional bur surgery for transposition of the inferior alveolar nerve to assess the effects on both soft and hard tissues. The study concluded that piezosurgery was more invasive to the bone than a conventional diamond bur, but the amount of injury was much lower than when using a conventional rotary bur (Metzger et al, 2006).

Atraumatic tooth extraction

When an implant is to be placed into a socket or area where a tooth is to be extracted, it is imperative to ensure minimal trauma to the surrounding bone to maintain as much bone as possible for integration of the implant.

Piezosurgical extraction consists of cutting the fibres of the periodontal ligament with vibrating tips of up to 10 mm in depth. The teeth can then be mobilised with an elevator. This method can be very useful with teeth that are ankylosed. Extractions performed in this way can be atraumatic, and render subsequent implant placement more predictable and easier compared to using burs (Blus and Szmukler-Moncler, 2010).

Peri-mucositis, peri-implantitis and calculus removal

Piezosurgery can be used in the treatment of peri-implantitis.

It can be used for soft tissue debridement to remove the secondary flap after incision through retained periosteum.

Using a thin tapered tip and altering the power setting, the piezosurgery device can also be used to debride the field of residual soft tissue and for root surface scaling to ensure thorough removal of calculus.

The piezosurgery system also allows removal of calculus from titanium osteosynthetic material quickly. Debris and infected bone can be removed from implant surfaces without damaging the implant.

This feature can also be beneficial when hard tissue has ingrown into screw slots, as it allows safe removal without damaging the screw itself to allow for screwdriver application (Robiony et al, 2007).

Conclusion

Before the widespread use of piezosurgery for osteotomies is accepted, possible side effects such as thrombogenesis or impaired blood circulation need to be examined. An area of particular concern is the poorly-vascularised mandible, where thrombosis of its intraosseous vessels may lead to obvious clinical problems of reossification of the osteotomy gap (Landes et al, 2008).

Long-term follow-up in larger patient numbers will prove whether seldom, yet serious, complications such as haemorrhage, aseptic necrosis, and facial nerve palsy may occur with smaller incidence compared with conventional techniques (Landes et al, 2008).

As this article demonstrates, however, there is an important role for piezosurgery in various clinical scenarios within dental implant treatment.

Piezosurgery can benefit the operator by allowing clear-cut precise osteotomies to be performed in a clear bloodless field without the risk of damaging soft tissues and nerves. The use of piezosurgery can equally benefit the patient by reducing postoperative swelling and trismus and speed up the recovery process.

In addition, the lack of osteonecrosis caused by piezosurgery and the positive effects on bone healing and osteogenesis mean that piezosurgery is a valuable tool to have within your dental implant armamentarium. **IDT**

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