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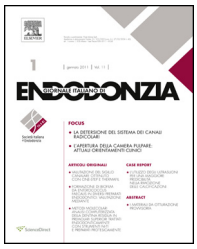

LITERATURE REVIEW/REVISIONE DELLA LETTERATURA

Diagnostic issues dealing with the management of teeth with vertical root fractures: a narrative review

Diagnosi della frattura verticale della radice in previsione di una sua corretta gestione clinica: revisione della letteratura

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KEYWORDS
Vertical root fracture;
CBCT;
Diagnosis;
Postextraction implant.

Abstract
Aim: The objectives of this study were to review the existing literature of vertical root fractures (VRFs) dealing with its management and to describe a classification for the bone defects resulting after extraction.
Methodology: An electronic search was performed on biomedical databases using a combination of appropriated search terms combined through the use of Boolean operators. A classification of the bone defects associated with vertical root fracture (VRF) was also proposed.
Results: Outcomes data extracted from the selected articles were summarized. Conventional radiography could fail in directly detecting the presence of VRF but can allow finding bone resorption areas which are related to the fracture itself. Tridimensional radiography (CBCT) may allow a better visualization of such bone defects. The bone defects associated to VRF could be

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classified on the basis of the number of walls affected and of the depth (in apico-coronal direction).
Conclusions: The diagnosis of VRF is a challenging process that includes both clinical and radiographic examination. In most cases, when postextraction implant was placed, guided bone regeneration is required to compensate the bone defect caused by VRF. A deep knowledge of the characteristics of the associated bone defect may allow an immediate and predictable substitution with dental implants, when tooth extraction is the only option.

PAROLE CHIAVE
Frattura verticale;
CBCT;
Diagnosi;
Impianti post-estrattivi.

Riassunto
Obiettivi: Lo scopo dello studio è stato valutare la letteratura riguardante le fratture verticali della radice (VRF) e la loro gestione clinica, illustrando una classificazione dei difetti ossei ad esse associate.
Materiali e metodi: È stata condotta una ricerca della letteratura utilizzando motori di ricerca elettronici, interrogati utilizzando una stringa preparata ad hoc.
Risultati: I risultati estratti dagli articoli selezionati sono stati riassunti. La radiografia convenzionale periapicale può non essere sufficiente per individuare con certezza la presenza di VRF ma può permettere di individuare aree di riassorbimento osseo, correlate alla frattura stessa. I difetti ossei associati alle VRF possono essere classificati sulla base del numero di pareti coinvolte e sulla sua dimensione apico-coronale.
Conclusioni: La diagnosi di VRF è un processo spesso complesso che deve includere una valutazione sia clinica sia radiografica. Inoltre, nel caso di estrazione, quando vengono posizionati impianti postestrattivi, la rigenerazione ossea è spesso fondamendale per compensar eil difetto osseo creato dalla VRF. Una conoscenza profonda delle caratteristiche del difetto osseo associate può consentire una sostituzione immediata e predicibile con impianti dentali, quando l'estrazione dell'elemento fratturato è l'unica opzione.

Introduction

The term vertical root fracture (VRF) refers to a fracture developing from apical or coronal portion of the root of a tooth and developing vertically along the root axis. These kinds of fractures can be complete or incomplete, and are usually directed facio-lingually[1].

VRF are more frequent in endodontically treated teeth[2,3] and it was hypothesized that it was because of an oversized root canal therapy that weakened canal dentin walls or of the presence of endodontic posts.[4] The continuous chewing forces lead to a higher prevalence of longitudinal fractures in treated teeth as compared to untreated.[5,6]

Chewing forces direction and entity seem to have an important role in determining the formation of a vertical fracture of root, also in non-treated teeth.[7]

The diagnosis of VRF may not be always easy due to lack of specific signs, symptoms and/or radiographic features, and due to many precipitating causes.[8] These limitations may lead to invasive diagnostic and exploratory surgical approaches to determine the presence of a VRF.[9,10]

Although, conservative approaches may be used to obviate extraction of the fractured tooth the prognosis of teeth with VRF is often poor.[9,11–13]

Under the circumstances a dental implant is considered the treatment of choice. But the success of the latter depends upon the timing and surgical approach which should be considered carefully based on the residual bone volume and the presence of any residual infection.[14] Even though the presence of a chronic infection in the site of implant placement could not be already considered as an absolute contraindication to implant placement, as it was shown in several systematic reviews of the literature,[15,16] this could have created bone resorptions and also complete disruptions of bony wall, limiting the possibilities of implant placement.

Literature has validated the use of guided bone regeneration to treat peri-implant bone defects at the time of implant placement.[17,18]

A recent systematic review of the literature proposed a classification of bone defects that can be associated to vertically fractured teeth.[19] In that paper, authors presented different clinical situations that can occur due to the infection spreading from the vertically fractured tooth. In all these cases, in order to obtain an adequate stability of the immediately placed implant, the application of guided bone regeneration procedures could be considered mandatory.

The aim of this narrative review of the literature was to revise the existing literature about the radiological and clinical diagnosis of vertical root fractures and to integrate the outcomes with the clinical classification of bone defects.

Materials and methods

An electronic search was performed on biomedical databases MEDLINE through Pubmed interface (http://www.pubmed.com), EMBASE (http://www.embase.com), and Cochrane Central Register of Clinical Trials (http://www.cochrane.org) using the following

search terms combined with the use of Boolean operators ("AND" and "OR"): "post extraction implants," "dental implant," "extraction socket," "bone defect," "bone dehiscence," "immediate implant," "immediate placement." No time nor language

restriction was applied. The last electronic search was performed in June 2012.

Inclusion criteria were study on humans about bone regeneration of dehiscence or fenestrations in the presence of implant fixture; clearly reposting data on implant demographics; description of the characteristics of the bone defects and the results in terms of bone filling rate.

Results

The initial web search yielded 373 articles. A total of 33 studies were included in the present review.

Twenty-three studies, describing the clinical outcomes of a total of 814 implants in dehisced sites, were considered for the analysis. The incidence of reported complications (mainly membrane exposures) reached up to 39%. A total of 10 studies reported techniques for the regeneration of vertical bone defects simultaneously with implant placement. A total of 429 implants were placed in 148 patients in sites with vertical bone defects. Guided bone regeneration with non-resorbable membranes and grafting was performed at 363 implant sites in 129 patients, while resorbable membranes were applied in 66 implant sites in 19 patients. No statistically significant differences in implant survival were reported between nonresorbable and resorbable barrier membranes among studies where such comparison was performed. A total of 10 studies have investigated GBR alone or in association with membranes for the management of fenestrations, concomitant to implant positioning.

Discussion

Diagnosis of vertical root fractures

The diagnosis of vertical root fractures could be difficult to be performed clinically because of the non-specificity of most of the clinical signs and symptoms. This is the reason why most of the vertical root fractures were diagnosed at the end of the prosthetic rehabilitation, leading to the failure of the whole treatment.[20]

Most common signs of vertical root fractures are the evidence of the presence of a deep periodontal pocket, often with bleeding on probing and even suppuration, and pain exacerbated through percussion of the involved tooth. Patients often refer pain during chewing and mild pain located at the gingiva.

Most of these signs and symptoms could be easily confounded with those dealing to the diagnosis of a periodontal lesion. In such terms, the clinical aspect of a vertical root fracture could mimic perfectly the one of a periodontal lesion, because VRF itself could lead to the loss of periodontal attachment apparatus, in conjunction with the presence of inflammation and infection.

However, the diagnostic process should include an accurate evaluation of the systemic and general oral conditions of the subject. Patients without periodontitis, in absence of foreign body dislocation in the periodontal space (e.g. cementum used to fix a prostheses) and of inadequate restorative and prosthetic restoration, could not suffer of a periodontal lesion. So, in periodontally healthy subjects and in absence of the previously cited conditions, the presence of a deep periodontal pocket should direct the diagnostic process to consider the diagnosis of VRF.[8]

Another aspect that should be considered carefully while considering the presence of a VRF is the fact that most of these occur in endodontically treated teeth, often in the presence of a post[2,3] while the presence of VRF in non-treated teeth is extremely rare.

So, exclusively from the clinical point of view, the presence of a VRF could be hypothesized on the basis of these parameters:

- periodontal involvement (presence of a narrow or wide deep periodontal pocket) with infection and inflammation signs, such as the presence of a highly located sinus tract[8]; this involvement could be obviously present also in periodontally healthy patients (Fig. 1)
- maxillary and mandibular premolars and the mesial roots of mandibular molars are the most affected tooth [8]
- pain at the percussion test or during chewing. The pain could be mild or severe in dependance of the extension and of the evolution of the lesion
- signs and symptoms associated to an endodontically treated tooth, in presence of a post.

Clinical diagnosis, based on signs and symptoms, must be corroborated by radiological investigation.

Using periapical radiographs, many figures could be associated to the presence of VRF.[8,21,22]

As an example, the "halo" appearance, that was described as either "combined periapical and perilateral radiolucency along the side of the root, lateral periodontal radiolucency along the side of the root, or angular radiolucency from the crestal bone terminating along the root side",[8] is often found in the presence of a VRF.[21] Other radiographic findings can be confounded with purely endodontic or periodontal lesions.[22] When VRFs occur in molars, radiolucency can be found also in the furcation area.[22] In all of these cases, radiographs were used as a mean to indirectly diagnose the presence of VRFs, without identifying the root fracture itself, which is very difficult to visualize in periapical radiographs (Fig. 2).

More recently, new technologies were applied to dental radiology in order to allow a tridimensional visualization of one oral region with an adequate resolution. Cone beam computed tomography was developed in the late 1990s,

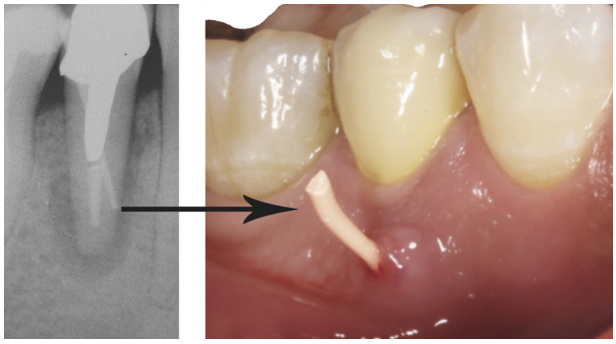

Figure 1 Deep probing depth and the presence of highly located sinus tract in a treated tooth may lead to the doubt of presence of VRF.

Figure 2 Periapical radiograph of a tooth with VRF. It is noticeable that the presence of VRF was not detectable and radiologic signs are few.

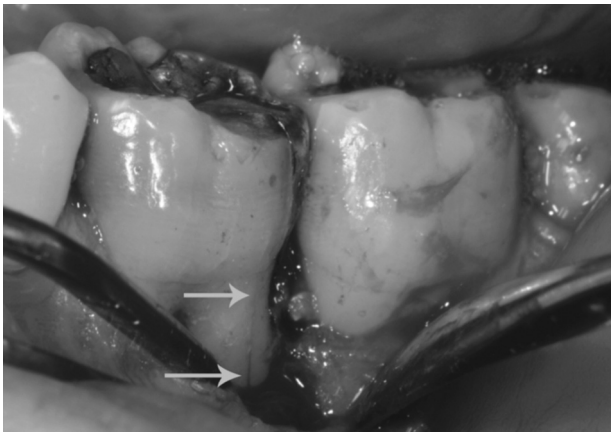

Figure 3 The surgical access allowed to directly visualize the presence of VRF.

aiming at reducing the dose of radiation if compared to conventional CT scans.[23,24]

One recent systematic review of the literature investigated the usefulness of CBCT in the diagnosis of VRFs.[25] After title and abstract selection, the authors included a total of 12 pertinent articles for the quantitative analysis.

The review investigated the sensitivity, specificity and accuracy of CBCT as compared to periapical radiographs, for detecting the presence of VRFs. In the review, *in vivo* studies showed that CBCT has a significantly higher sensitivity than periapical radiography, in particular when using a voxel size smaller than 0.2 mm. On the contrary, specificity was found to be high also in periapical radiography and comparable to that of CBCT. *In vitro* studies on non-filled teeth showed high ($>$0.90) specificity for CBCT when voxel size was less than 0.3 mm while sensitivity was less than 0.90 when voxel size was less than 0.25 mm. Periapical radiography showed a markedly lower sensitivity than CBCT groups when voxel size was less than 0.25 mm. The presence of endodontic filling was shown to alter the accuracy parameters of radiologic devices as shown in the analysis of such in vitro studies.

The authors concluded that the CBCT ability to detect the presence of VRF could depend on a number of factors such as voxel size and the presence of endodontic fillings or post. However the possibility of a tridimensional visualization of the bone defect can allow to evaluate also post-extraction positioning of dental implant in substitution of loss tooth.[19]

So, radiology could importantly help in the diagnosis of VRFs even though, also using advanced tridimensional techniques, the direct and clear visualization of the fracture itself is often impossible.

In doubtful cases, the option to perform a surgical access flap is necessary to confirm the presence of VRF through direct visualization.[26,27]

Surgical access allows a certain diagnosis, and, in some cases, also the immediate extraction of the fractured tooth and its substitution with a dental implant (Fig. 3).

Bone defects associated to vertical root fractures

The presence of a vertical root fracture causes the communication between a potentially infected root canal and the space of the periodontal ligament. Moreover, the presence of the fracture itself can cause the irritation of the periodontal ligament, inducing the formation of a bone defect that follows the spread of inflammation.

As VRF could evolve in complete tooth split,[1] in the same way the bone defect that is caused could evolve both in depth and in height over time.

Despite some challenging treatment options were proposed to maintain teeth with incomplete VRF,[9] the treatment of choice of teeth with root fractures is the extraction and, potentially, its substitution with a dental implant.

Bone volume is one of the key factors to be considered when evaluating implant placement. In particular, in the presence of insufficient bone volume, implant placement could be conditioned by the necessity of performing bone grafting procedures to compensate bone absence. Under these circumstances, the classification of bone defects associated to VRFs should consider the possibility of implant placement with or without guided bone regeneration.

Recently, a systematic review addressing this issue was published, with the specific aim of classifying the bone defects relating them to the outcomes of implant treatment in those cases[19] (Table 1).

Defects located just on the buccal (or lingual) wall, and both V- and U-shaped were classified as Class I defects. The depth of the defect (apico-coronal direction) served to distinguish Class Ia (the less deep), Class Ib, and Class Ic (deeper) defects (Fig. 4). If an implant is placed in such conditions a dehiscence at implant site could occur, causing threads exposition. The literature suggests that the use of both resorbable and non-resorbable membranes is predictable to cover such defects after implant placement, leading to the resolution of the clinical problem. Even though the application of non-resorbable barriers could lead to better outcomes if compared to resorbable ones, the risk of exposition and the more challenging positioning procedure require a higher operator skill.[19]

Table 1 Classification of bone defects by Corbella & Taschieri et al.[19]

Class	Description
Class I	Affecting only buccal or lingual/palatal wall without involvement of interdental bone. Subclasses: Class Ia (less deep); Class Ib; Class Ic (the deepest)
Class II	Affecting buccal or lingual/palatal wall with involvement of interdental bone. Subclasses: Class IIa (less deep); Class IIb; Class IIc (the deepest)
Class III	Affecting only the apical portion; fenestrations

Defects affecting also interdental bone were classified as Class II defects (Fig. 5). The loss of interdental bone and consequently of the bone peak may require a vertical regeneration after implant placement. Vertical bone regeneration was applied in several studies, often with the use of non-resorbable barrier membranes.[28] Despite the outcomes of such treatment, as presented in the available literature, were substantially good, it should be highlighted that the surgical skills of the operator appears to be crucial to determine the success of the procedure. Moreover, more randomized trials are needed to understand the indications of such treatment options in comparison to other surgical and prosthetic alternatives.

Class III defects are fenestrations, usually associated to an incomplete fracture developing from the apex along the root (Fig. 6). In most of these cases guided bone regeneration is not needed in order to obtain the success of implant treatment.

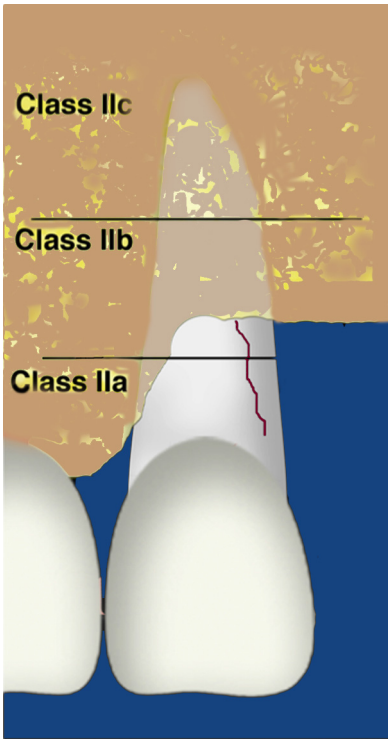

Figure 5 Class II defects.

On the basis of the presented classification, a complete knowledge of the anatomy of the bone defect associated to a tooth with VRF may help in the evaluation of the treatment protocol to be adopted to substitute the affected tooth with a dental implant. Considering the development of VRFs over

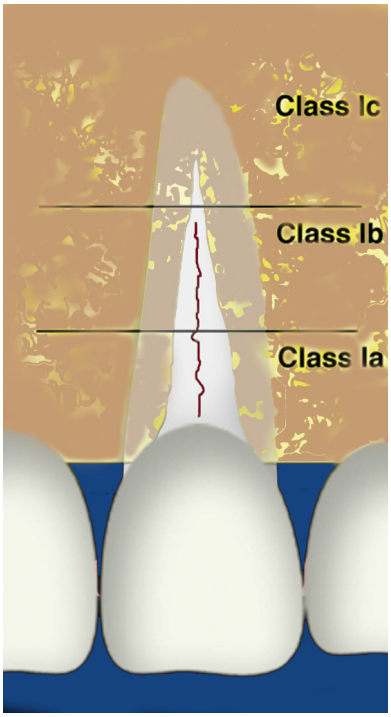

Figure 4 Class I defects.

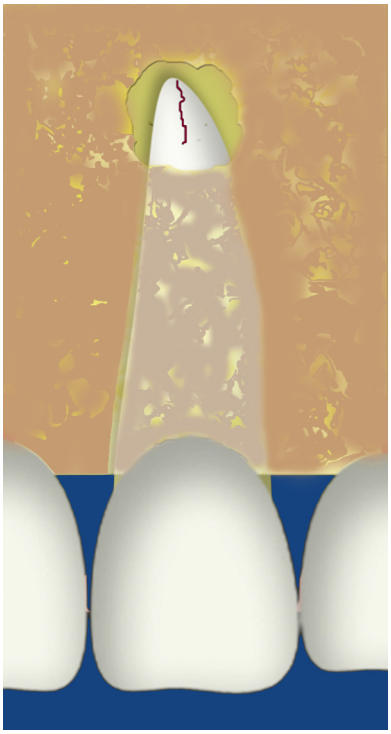

Figure 6 Class III defect.

time, it should be considered that the sooner the diagnosis the less the size of the associated bone defect.

Conclusions

On the basis of the present narrative review of the recent literature about VRFs diagnosis and characteristics of bone defects it can be concluded that:

- VRFs are often hard to diagnose because most of the clinical signs and symptoms could mimic other more frequent pathologies
- Radiologic examination almost always did not allow a direct visualization of the VRF itself but just of the bone defects associated
- Tridimensional radiology with adequate settings could help in the indentification of a tooth with VRF together with the clinical examination
- In doubtful cases access flap surgery could be the only option for a certain diagnosis
- An accurate knowledge of the anatomical characteristics of the bone defect associated to fractured tooth is mandatory for an accurate planning for postextraction implant placement.

Conflict of interest

The authors have no conflict of interests to declare.

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