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Evaluation of factors related to the maintenance of avulsed permanent teeth

Avaliação dos Fatores Relacionados à Permanência de Dentes Permanentes Avulsionados Reimplantados

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ABSTRACT
Objectives: *Identify factors that influence favourable outcomes and maintenance of avulsed permanent teeth.* **Methodology:** *A retrospective study was carried out involving avulsed and reimplanted permanent teeth of patients treated from 2012 to 2024 by a Dental Trauma Group. Data such as gender, age, tooth, degree of rhizogenesis, storage medium, extra-alveolar and follow-up time were collected for descriptive analysis. Clinical and radiographic data were classified into outcomes: functional healing (FH), infection-related (inflammatory) resorption and/or pulp necrosis (IRR), replacement resorption (RR) and revascularisation (RV). Comparative analyses were performed using Fisher's exact test, and survival was performed using the Kaplan-Meier survival curve and Cox analysis.* **Results:** *The sample consisted of 30 teeth. The average follow-up time was 41.7 months. The average age was 13 years, and the most affected teeth were the upper front teeth. After reimplantation, three teeth were revascularized and did not require endodontic intervention, 4 had RV, 10 RR and 13 with IRR. In the analysis of the survival curve (p=0.01), mature teeth had a lower survival rate compared to immature teeth, reducing to 68% in 36 months, progressing to IRR.* **Conclusion:** *It was observed that immature teeth presented better outcomes than mature ones, and storage in physiological media presented lower chances of IRR, demonstrating that initial measures significantly impact clinical outcomes and survival of reimplanted avulsed teeth.*
Key Words: *Tooth Injuries, Tooth Avulsion, Tooth Replantation.*

RESUMO
Objetivos: Identificar os fatores que influenciam os desfechos favoráveis e a manutenção de dentes permanentes avulsionados. **Metodologia**: Foi realizado um estudo retrospectivo envolvendo dentes permanentes avulsionados e reimplantados de pacientes atendidos entre 2012 e 2024 por um Grupo de Trauma Dentário. Foram coletados dados como gênero, idade, dente, grau de rizogênese, meio de armazenamento, tempo extra-alveolar e de acompanhamento para análise descritiva. Os dados clínicos e radiográficos foram classificados nos desfechos: cicatrização funcional (CF), reabsorção inflamatória relacionada à infecção e/ou necrose pulpar (RI), reabsorção por substituição (RS) e revascularização (RV). As análises comparativas foram realizadas utilizando o teste exato de Fisher e a sobrevida foi avaliada por meio da curva de sobrevida de Kaplan-Meier e análise de Cox. **Resultados**: A amostra foi composta por 30 dentes. O tempo médio de acompanhamento foi de 41,7 meses. A média de idade foi de 13 anos e os dentes mais acometidos foram os anteriores superiores. Após o reimplante, 3 dentes foram revascularizados e não necessitaram de intervenção endodôntica, 4 apresentaram RV, 10 RS e 13 RI. Na análise da curva de sobrevida (p = 0,01), dentes maduros apresentaram menor taxa de sobrevida em comparação aos imaturos, reduzindo para 68% em 36 meses, evoluindo para RI. **Conclusão**: Observou-se que dentes imaturos apresentaram melhores desfechos do que os maduros e que o armazenamento em meios fisiológicos apresentou menores chances de RI, demonstrando que as medidas iniciais impactam significativamente os desfechos clínicos e a sobrevida de dentes reimplantados após avulsão.
Palavras-chave: Traumatismos dentários, Avulsão dentária, Reimplante dentário.

INTRODUCTION

Dental trauma constitutes a major global public health issue and frequently leads to the development of lesions in teeth and supporting tissues[1–3]. The prognosis of traumatised teeth is largely determined by the quality and promptness of immediate management, as delays or errors in emergency care may result in long-term complications[4].

Dental avulsion is one of the most severe dentoalveolar injuries, characterised by the complete displacement of the tooth from its socket, occurring most frequently

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in children aged 7 to 9 years. Its long-term prognosis depends on favourable dental pulp and periodontal tissue healing[5,6]. The treatment of an avulsed tooth requires specific care, both during the emergency phase and throughout post-trauma follow-up, as the loss of a reimplanted permanent tooth, even after repositioning into its original socket, is also a common complication[6,7].

After avulsion, the tooth sustains damage to the periodontal ligament (PDL) fibres and the cementum layer. If kept hydrated, PDL cells that remain on the root surface can retain their viability, thereby enabling healing after reimplantation without inducing significant inflammation[8]. The International Association of Dental Traumatology (IADT) recommends that an avulsed tooth be reimplanted immediately. However, if immediate reimplantation is not feasible, the tooth must be stored in a liquid medium such as Hanks' Balanced Salt Solution, milk, saliva, or saline[9].

Pulp necrosis is a common complication of dental avulsion, due to the rupture of the neurovascular bundle, which renders the root canal susceptible to bacterial contamination. Combined with damage to the cementum layer, this often leads to external inflammatory resorption[8]. This type of resorption is aggressive, and its progression can result in rapid tooth loss. Consequently, early endodontic treatment is essential, particularly in teeth with complete root development, to eliminate or prevent this form of resorption[8,10–12].

Damage to the root surface initially drives an inflammatory response, followed by the formation of a diffuse area lacking cementum. Once covered by osteoblasts, the contact between bone and the dental root initiates a process known as dentoalveolar ankylosis. Combined with the active resorptive action of osteoclasts, this process leads to the gradual replacement of cementum by bone[1].

Global literature reveals significant variability in the survival rates of reimplanted teeth, with a reported prevalence of 57% to 80%. Several avulsed and reimplanted teeth can remain functional in the oral cavity for years [13]. However, a lack of awareness regarding these complications, coupled with inadequate treatment and follow-up, can lead to tooth loss, resulting in functional, aesthetic, psychological, and social consequences for affected individuals[6].

Considering the absence of data in the literature regarding the survival rates of avulsed and reimplanted teeth treated at a dental trauma-specialised health centre in the state of Bahia, this study aims to identify factors influencing favourable outcomes and the long-term retention of avulsed permanent teeth.

MATERIALS AND METHODS

This study was approved by the Research Ethics Committee of the School of Dentistry at the Federal University of Bahia (FOUFBA) (Appendix 1). All patients or their legal guardians were informed about the protocols, risks, and benefits of participation and signed a free and informed consent form or an assent form authorising their participation in this research.

The sample consisted of patients who suffered dental avulsion and were treated at FOUFBA between 2012 and 2024. Inclusion criteria encompassed the records of patients with avulsed and reimplanted permanent teeth. Exclusion criteria included records of patients with avulsed teeth that appeared to be deciduous on radiographic examination, previous endodontically treated teeth, and patients who did not return for follow-up after reimplantation.

All treatments were performed by undergraduate students who were properly trained and supervised by the professor coordinating the research. The procedures followed the protocols recommended by the International Association of Dental Traumatology (IADT)[9], which primarily involve the use of flexible splints for two weeks, endodontic treatment with intracanal medication changes using calcium hydroxide or calcium silicate-based materials, obturation, and clinical and radiographic follow-ups. In cases of immediate reimplantation or teeth with incomplete root formation, extended follow-up was preferred before initiating endodontic intervention due to the possibility of revascularization[14].

After a thorough review of the patient records, the following data were collected: age, gender, tooth involved, extra-alveolar time (up to 60 minutes or ≥ 60 minutes), root development stage, storage medium used, and follow-up duration (post-trauma). The root development stage was assessed using periapical radiographs and classified according to the stages described by Cvek et al. (1992)[15]: 1: <½ root length; 2: ½ root length; 3: ⅔ root length; 4: open apical foramen and nearly complete root length; 5: closed apex and fully developed root. In the present study, teeth were categorised as immature (stages 1 to 4) or mature (stage 5). Regarding the storage media for avulsed teeth, saline solution, milk, the oral cavity, or saliva were classified as Physiological Media, whereas teeth stored in dry media, such as papers or towels, were categorised as Non-Physiological Media[15].

Clinical records such as oedema, dental mobility, pulp necrosis, tenderness to palpation or percussion, and infra-occlusion were also noted. The presence or absence of external root resorption was recorded based on the analysis of follow-up periapical radiographs from the patient's records.

The clinical/radiographic outcomes were analysed and classified based on the study by Petrovic et al. (2010) into the following categories: functional healing (FH), infection-related (inflammatory) resorption and/or pulp necrosis (IRR), replacement resorption (RR) and revascularisation (RV). The outcome was classified as FH when no complications related to infection or ankylosis were present (absence of pain symptoms on palpation and percussion, no periapical lesions, no mobility or infra-occlusion, and an intact lamina dura). RR was classified

when the tooth exhibited one or more of the following criteria: a metallic sound upon percussion, no mobility, infra-positioning, loss of periodontal ligament space, or replacement of the root with bone. IRR was classified when clinical signs of infection (oedema, pain, fistula, tenderness to palpation and percussion) and/or apical or lateral radiolucent areas of the root were present. Teeth that exhibited continued root development and did not require endodontic treatment during the follow-up period were classified as revascularized (RV)[15]. The collected data were organised in Excel spreadsheets (Microsoft, Seattle, WA, USA), tabulated into graphs and tables with the percentage distribution of occurrences for each evaluated topic, and analysed.

The dependent variables are nominal qualitative types and include the outcomes: RV, FH, RR, and IRR. The independent variables are also nominal qualitative types: storage medium, root development stage, and time to reimplantation. Comparative analyses were performed using Fisher's exact test. Survival analysis regarding root development at the time of trauma, time to reimplantation, and storage medium for the IRR outcome over 60 months was conducted using Kaplan-Meier survival curves and Cox analysis. Descriptive analyses for patient age, follow-up duration, and sex are presented as measures of central tendency and frequency. All analyses were performed using Jamovi software version 2.3.28.0. A significance level of $p < 0.05$ was adopted.

RESULTS

A total of 40 patient records involving dental avulsion were analysed, accounting for 60 avulsed permanent teeth. Of these, only 43 teeth were reimplanted, resulting in the exclusion of 10 patient records from the sample. An additional seven records were excluded because the patients did not return for follow-up after reimplantation. The final sample consisted of 23 patients, totalling 30 teeth under follow-up. Among the patients, 13 were male (56.7%) and 10 were female (43.3%). The post-trauma follow-up period ranged from 2 to 144 months, with a mean of 34.5 months. The age at the time of trauma ranged from 5 to 36 years (mean of 13 years), and the most affected teeth were the maxillary central incisors (n=21, 70%), followed by the maxillary lateral incisors (n=3, 10%) (Table 1).

The time that the teeth remained out of the alveolus before reimplantation ranged from 15 minutes to 96 hours. Among the 30 teeth analysed, two were reimplanted immediately, six were reimplanted within 60 minutes, and 22 were reimplanted after 60 minutes. Regarding the storage media used for the teeth before reimplantation, 15 were kept in non-physiological media, while 13 were kept in physiological media (2 teeth were stored in milk, 6 in the patient's oral cavity, and 5 in saline solution). At the time of trauma, 24 teeth had complete root development/mature roots, and 6 had incomplete root development/immature roots. After reimplantation, three teeth underwent revascularisation, with continued root development and calcification, without the need for endodontic treatment (RV = 10%). Among the traumatic outcomes evaluated for the remaining 27 teeth, 4 (13.3%) exhibited Functional Repair (FR) with no signs of infection. Replacement Root Resorption (RRR) was diagnosed in 10 teeth (33.3%), and Inflammatory Root Resorption and/or Pulp Necrosis (IRR) occurred in 13 teeth (43.3%) (Table 2). To better reflect the outcomes, the stratification by 16 years old was based on the estimated age of root apex closure, as this has a significant impact on the progression of the cases and more accurately reflects the potential outcomes.

Table 1 – *Distribution of the Sample According to Demographic Data*

	COUNT	% PERCENTAGE
GENDER		
Male	*13*	*56,7%*
Female	*10*	*43,3%*
AGE		
<16 years	*18*	*78,3%*
≥16 years	*5*	*21,7%*
TOOTH INVOLVED		
Maxillary central incisor	*21*	*70,0%*
Maxillary lateral incisor	*3*	*10,0%*
Mandibular central incisor	*3*	*10,0%*
Mandibular lateral incisor	*2*	*6,7%*
Maxillary canine	*1*	*3,3%*

Table 2 – *Percentage Distribution of Variables and Comparison with Clinical/Radiographic Outcomes.*

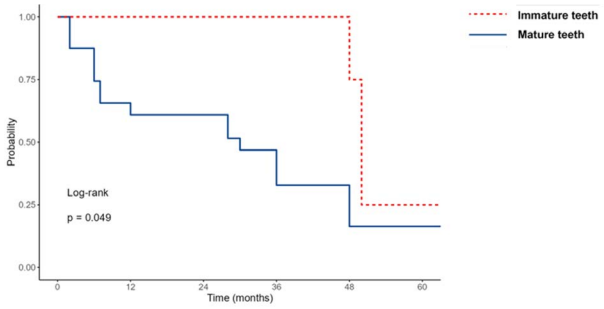
	N %	RV	FH	RR	RRI	Pvalor
EXTRA-ALVEOLAR TIME						
<60 min	*8 (26,3%)*	*1 (12,5%)*	*1 (12,5%)*	*4 (50,0%)*	*2 (25,0%)*	*0,606*
≥60 min	*22 (73,7%)*	*2 (9,1%)*	*3 (13,6%)*	*6 (27,3%)*	*11 (50,0%)*	
STORAGE MEDIUM						
Physiological	*15 (50,0%)*	*2 (13,3%)*	*3 (20,0%)*	*6 (40,0%)*	*4 (26,7%)*	*0,338*
Non-physiological	*15 (50,0%)*	*1 (6,7%)*	*1 (6,7%)*	*4 (26,7%)*	*9 (60,0%)*	
ROOT STAGE						
Immature	*6 (20,0%)*	*3 (50,0%)*	*0 (0,0%)*	*1 (16,7%)*	*2 (33,3%)*	*0,010*
Mature	*24 (80,0%)*	*0 (0,0%)*	*4 (16,7%)*	*9 (37,5%)*	*11 (48,8%)*	

Abbreviations: FH, Absence of infection/ankylosis; RR, Substitutive Root Resorption; RRI, Inflammatory Root Resorption and/or Pulp Necrosis; RV, Revascularized. Fisher's exact test

In the analysis of the Kaplan-Meier survival curve, teeth with closed apices at the time of avulsion demonstrated lower survival rates (a 40% reduction in survival at 12 months) compared to teeth with open apices, with survival rates declining to 68% at 36 months, progressing toward inflammatory resorption or pulp necrosis. In other words, patients with closed apices at the time of avulsion exhibited a statistically higher risk of developing pulp necrosis during the recorded follow-up period. When the affected tooth was immature, the risk of progressing to inflammatory root resorption and/or pulp necrosis (RRI)

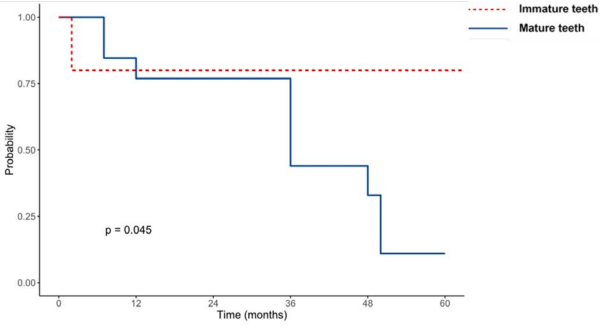
was 0.46 times lower than in teeth with closed apices (Figure 1, Kaplan-Meier p = 0.04).

Figure 1 – *Survival curve for teeth with closed and open apices at the time of avulsion regarding the outcome of RRI over 60 months (Kaplan-Meier p = 0.04).*



Regarding storage media, teeth stored in physiological media remained in the oral cavity during the evaluation period and showed more favourable clinical outcomes compared to those stored in a dry medium. Dry storage significantly influenced a higher number of cases with RRI, resulting in a 26% reduction in survival at 12 months and 40% at 24 months for teeth stored in dry media. When the storage medium was physiological, the risk of developing RRI was 0.38 times lower compared to dry storage (Figure 2, Kaplan-Meier p = 0.04).

Figure 2 – *Survival curve for teeth stored in dry or physiological media after avulsion regarding the outcome of RRI over 60 months (Kaplan-Meier p = 0.04).*



DISCUSSION

The prevalence of dental avulsion in permanent teeth ranges from 0.5% to 16%, with permanent teeth being more affected than primary teeth. [1,15,16]. In the present study, a retrospective descriptive analysis of reimplanted avulsed permanent teeth was conducted, with an average follow-up of 3 years, to evaluate the variables that most influenced the maintenance of these teeth as functional units in the oral cavity. Most of the sample consisted of young patients (mean age of 13 years) and males (56.7%), consistent with the proportions observed in other clinical studies on dental avulsion[6,17–19]. The most affected teeth were the upper incisors, corroborating findings in the literature suggesting that the high risk of traumatic dental injuries in maxillary incisors may be associated with their anterior position and, in some cases, with increased overjet and inadequate lip coverage[20–23].

The prognosis of avulsed and reimplanted permanent teeth is directly influenced by the actions taken at the time of the accident and during long-term treatment, aiming to minimise possible sequelae such as root resorption, pulp necrosis, ankylosis, and pulp obliteration[4,5,7,21,24]. Reimplantation should be immediate to promote the reattachment of periodontal fibres and increase the chances of tooth retention. However, this study observed that reimplantation was delayed in most cases (n = 22), occurring only after 60 minutes. This prolonged extra-alveolar period negatively affected repair, as a high percentage of resorptions was observed (RR = 50% and RR = 27.3%), while functional repair (FH) occurred in only 13.6% of cases. This outcome is due to the desiccation and non-viability of the periodontal ligament (PDL) cells adhered to the root surface, which initially respond with inflammation and subsequently develop a diffuse area without cementum, leading to a process known as ankylosis. Combined with the active action of osteoclasts, this results in replacement resorption[8,21,22,25,26]. These findings are consistent with the literature, which identifies extra-oral time as one of the most significant factors influencing periodontal healing[10,23].

Although no significant association was found between storage media and the evaluated outcomes, there is biological relevance described in the literature regarding the importance of the storage medium during the extra-alveolar period until reimplantation. This is critical for the preservation of periodontal ligament cells, which directly impacts the prognosis. For this reason, we evaluated the survival of teeth stored in different media. When immediate reimplantation is not possible, temporary storage in a moist medium, preferably milk, can be employed in an attempt to preserve the viability of periodontal ligament (PDL) cells. This practice is recommended by the IADT [14]. The reasons include its high efficacy due to its pH and osmolarity, which are physiologically compatible with the PDL cells adhered to the root surface, as well as its low bacterial content, presence of growth factors, and essential nutrients for cell survival. Additionally, milk is easy to obtain and cost-effective[27]. In this study, although no statistically significant difference was observed, 60% of cases with RRIN involved teeth stored in non-physiological (dry) media, which are unsuitable for cellular preservation. This finding aligns with studies suggesting that physiological media, such as milk, can reduce inflammatory resorption and increase the survival rates of reimplanted teeth[6].

Some reports have demonstrated an association between reimplanted avulsed teeth that clinically progressed to RRIN and the age of the patient at the time of trauma, with younger patients being more affected. The same authors observed that patients over 16 years old had a

lower likelihood of developing RRIN. This can be attributed to the higher activity of clastic cells, which is responsible for resorption in younger patients. Additionally, younger teeth have wider dentinal tubules, which facilitate the accumulation of a larger number of bacteria and necrotic content. These factors more readily flow to the external surface of the root, potentially accelerating the RRIN process in this population[6,28].

The present study demonstrated a contrasting association, where teeth with open apices in younger patients showed higher survival rates and lower resorption rates. When the affected tooth was immature, the risk of progressing to RRI was 0.46 times lower compared to teeth with closed apices. Furthermore, teeth with closed apices exhibited a 68% reduction in survival within 12 months of follow-up. These findings may be associated with measures taken during the first hours after avulsion, such as the use of physiological storage media and a reimplantation time of less than 60 minutes, which contributed to increased survival and the possibility of repair, preventing or reducing the activity of clastic cells on the root surface.

In reimplanted immature teeth, there is the possibility of spontaneous revascularisation with the formation of new connective tissue with a blood supply, allowing for continued root development and apex closure. In the present study, as well as in others, a considerable proportion of immature teeth (50%) achieved pulp revascularisation, highlighting the importance of conservatively monitoring reimplanted immature teeth[6,27]. However, once the first signs of infection are detected and revascularisation does not occur, endodontic intervention should be promptly performed, as inflammatory root resorption progresses very rapidly in children[23,29–31].

In this study, we observed avulsed teeth that were reimplanted and managed to maintain their aesthetic, phonetic, and masticatory functions for up to 12 years. Thus, the recommendation to reimplant all avulsed permanent teeth, even in late cases, can once again be emphasised, aiming to preserve the contour, width, and height of the alveolar bone with the possibility of future treatments, especially when dealing with young patients who cannot receive implant rehabilitation[22,27,32,33].

As a retrospective descriptive study, the analysis relied on previously recorded data, which may be incomplete or inconsistent. This can limit the depth of the analysis and the ability to control for confounding variables. Since the study was conducted in a specific region (e.g., Bahia, Brazil), socioeconomic factors and access to emergency dental care might limit the applicability of findings to populations in different settings.

Further randomised clinical follow-up studies with larger sample sizes are needed to make additional correlations, in order to enhance the understanding and treatment of challenging dental avulsion cases. Moreover, it is crucial to implement educational campaigns and programs aimed at raising public awareness regarding the proper management of avulsed teeth, emphasizing the importance of immediate reimplantation and, when this is not possible, the storage of the tooth in an appropriate medium, such as milk, with the goal of improving the prognosis of reimplanted teeth.

CONCLUSION

Most avulsed permanent teeth exhibited endodontic changes and external root resorption, necessitating endodontic interventions and long-term follow-up of these sequelae. Pulp vitality, although less likely, is still possible, particularly in cases of immature permanent teeth with an extra-alveolar period of less than 60 minutes. Immature teeth showed better clinical/radiographic outcomes compared to teeth with completed root formation, and teeth stored in physiological media had lower chances of inflammatory root resorption, demonstrating that initial measures in avulsion cases significantly impact the clinical outcomes and survival of reimplanted avulsed teeth.

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