

The cost of dental trauma in children: a one-year prospective study

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DECLARATION

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Summary

Background: Traumatic Dental Injuries (TDI) to the permanent dentition in children and adolescents are common. Management of these injuries can be expensive, time-consuming and often continues into adulthood. Very few studies have addressed the cost of dental injuries.

Aims: The purpose of this study was to estimate the total costs of treating dental injuries to the permanent dentition in children and adolescents over a one-year period and to investigate the factors that influence the total cost.

Materials and methods: Children (aged 6-16 years) with traumatic injuries to permanent incisors were enrolled. Injuries were grouped into complicated and uncomplicated and were also divided by the date of injury. Costs were defined as direct (capital/overhead costs, operator and nursing staff cost, cost of dental treatment, medications, radiographs and laboratory fees) and indirect costs (travel costs, childcare costs and production loss). Costs were collected prospectively at each visit through hospital records and self-completed questionnaires. Each patient was followed up for a period of one year. Data were analysed using a linear regression model.

Results: Ninety-five patients (60 males and 35 females) with a mean age of 10.5 years were included in the statistical analysis. Seventy-four (77.89%) children had complicated injuries compared to 21 (22.11%) patients with uncomplicated injuries. More than half of the injuries (53.68%) were less than one year old.

The mean number of visits required over the study period (one year) was 5.4 regardless of the injury group, with a range of 1-14 visits. The highest number of visits (6.1) required for treatment of injuries occurred in the first year. This number declined over time and was 5.5 and 3.6 visits for injuries in the second and third year of management and for injuries older than 4 years respectively over one year. Age and gender did not influence the number of visits.

The total cost in one year was estimated to be €1687.9 (SD=1129.9) and €1350.8(SD=800.6) for complicated and uncomplicated injuries respectively. This difference was not statistically significant (p-value =0.13). However, when new injuries in the first year were analysed separately, a statistically significant difference (p-value<0.001) was noted between the two injury groups. The total cost for complicated injuries was €1977.2 (SD=1021.1) compared to €1000.9 (SD=590.6) for uncomplicated injuries during the first year.

When analysed by injury date, the total cost was slightly higher (€1845.8(SD=1265.7)) for injuries in the second and third year of management compared to those within the first year (€1766.7(SD=1023)). This cost was significantly less (€895.9(SD=512.4) for injuries older than 4 years. However, linear regression analysis revealed statistically significant association between the total cost and the injury date only for injuries in the second and third year and not for older injuries, which may be due to the small numbers in the latter group. Age and gender did not significantly influence the cost.

The linear regression analysis showed that the number of visits and the distance travelled were other important predictors of the total cost. It was estimated that the total cost will increase 25% for every additional visit. The distance travelled also influenced the cost, however, there was a wide variation in the form and cost of transport.

Conclusion: Management of traumatic dental injuries is costly and time-consuming particularly for complicated injuries in the first year. Complicated injuries were almost twice as expensive as uncomplicated injuries in the first year. The highest number of visits was required for complicated injuries within the first year after the trauma. Management of injuries in the second and third year can be still expensive; however the total cost and the number of visits tend to reduce thereafter. This study provides estimation of the annual costs for traumatic injuries in this cohort of patients in one year. Further research in this area is encouraged to add to the limited available data.

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CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1. Epidemiology of dental trauma in the permanent dentition

1.1.1. Prevalence

Childhood accidents are common. Among all body injuries, oral injuries were the third most common in school children accounting for 5% of all body injuries (Petersson et al., 1996). This proportion is considered significant as the oral cavity comprises only 1% of the total body area. Of oral injuries, dental injuries were the most common constituting more than 90% in the age group 7-15 years (Petersson et al., 1996).

Traumatic Dental Injuries (TDI) in the permanent dentition are common. Variable prevalence figures have been reported across the world. In a recent review of the literature, the reported figures ranged from 6 to 59% in primary and permanent teeth in children and adolescents (Lam, 2016). This variation may be due to sampling and methodological differences among studies, but it could be also attributed to the variable nature of dental trauma. There is wealth of literature regarding TDI prevalence in the permanent teeth in children. Table 1.1 summarises the prevalence of TDI in the permanent dentition reported over the last decade across the world. From the table, the prevalence ranges from 6% to 34.8% in the ages 6-19 years. This wide range can be attributed to cultural and environmental differences across the world and maybe also due to methodological variation among the studies.

Table 1.1: Prevalence of TDI in the permanent dentition in children and adolescents(2007-2017)

Author	Country	Sample size	Age (years)	Percentage
(Soriano et al., 2007)	Brazil	1046	12	10.5%
(Fakhruddin et al., 2008)	Canada	2422	12-14	11.4 %
(Adekoya-Sofowora et al., 2009)	Nigeria	415	12	12.8%
(David et al., 2009)	South India	838	12	6%
(Altun et al., 2009)	Turkey	4956	6-12	9.5%
(Noori and Al-Obaidi, 2009)	Iraq	4015	6-13	6.1%
(Naidoo et al., 2009)	South Africa	1665	11-13	6.4%
(Thelen and Bårdsen, 2010)	Albania	2789	16-18	9.9%
(Huang et al., 2009)	Taiwan	6312	15-18	19.9%
(Bendo et al., 2010a)	Brazil	1612	11-14	17.1%
(Navabazam and Farahani, 2010)	Iran	1440	9-14	27.56%
(Taiwo and Jalo, 2011)	Nigeria	719	12	15.2%
(Kumar et al., 2011)	India	963	12-15	14.4 %
(Piovesan et al., 2011)	Brazil	792	12	9.7%
(Jorge et al., 2012)	Brazil	891	15-19	24.7 %
(Schuch et al., 2013)	Brazil	1210	8-12	12.6%
(Martins et al., 2012)	Brazil	590	7-14	12.7%
(Damé-Teixeira et al., 2013b)	Brazil	1528	12	34.8%
(Patel and Sujana, 2012)	India	3708	8-13	8.8%
(Dua and Sharma, 2012)	India	880	7-12	14.5%
(Francisco et al., 2013)	Brazil	765	9-14	16.5 %
(Aldrigui et al., 2014)	Central America countries	2436	12	15-20 %
(Goettems et al., 2014)	Brazil	1210	8-12	12.6%
(Oliveira Filho et al., 2014)	Brazil	687	14-19	26.6 %
(Ain et al., 2016)	India	1600	12	9.3%
(Gupta et al., 2016)	India	1518	11-15	10.7%

Males are often more prone to TDI than females. The reported male: female ratio is averaged as 2: 1 (Glendor, 2008). This could be explained by greater engagement of boys in sports, traffic accidents and violence or fights. However some recent research reported increased TDI among girls and attributed that to their increased interest in sports (Traebert et al. 2006)

Overall these studies make it clearly discernible that dental trauma is common with high prevalence rates.

1.1.2. Incidence

In contrast to prevalence studies, there is a paucity of studies reporting on the incidence of dental trauma. This might be attributed to the cost and complexity involved in designing such studies. Incidence studies seek to estimate the rate of occurrence of new cases; therefore they are more lengthy and costly in nature. Most of the incidence data on dental trauma are drawn from studies involving the Scandinavian population where the government provides free dental treatment and recall- appointments at the public health service for all children and adolescents. This facilitates access to dental care and reduces the financial constraints involved in collecting large data sources needed for this type of research. In a large longitudinal multicentre study in Sweden, Oldin et al. reported the yearly incidence of TDI in different age cohorts. The study reported a rate of 3.3% , 1.2% and 1% for the age groups 7, 11 and 15 years in the permanent dentition (Oldin et al., 2015).

In a recent review of the literature, the overall reported annual incidence of TDI in children and adolescents aged 0-19 years was estimated to be 4.5% (Lam et al.

2016). However, the latter number was based on mixed data from primary and permanent dentitions.

A small number of incidence studies have been carried out outside Scandinavia (Table 1.2); in Australia (Stockwell, 1988); UK (Hamilton et al., 1997); and Brazil (Ramos-Jorge et al., 2008). These studies reported the incidence rate for TDI in the permanent dentition in children. As shown in the table, the incidence rate ranges from 1 to 34 new cases in 1000 individual in one year. This variation may reflect regional, cultural and environmental differences across the world.

Table 1.2: Incidence of TDI in the permanent dentition in children and adolescents.

Study	Country	Sample	Age	Annual incidence(per 1000 /year)
Stockwell 1988	Australia	66,500	6-12	17
Hamilton et al. 1997	UK	2022	11-14	34
Ramos-Jorge et al. 2008	Brazil	2260	11-13	1.2-5.75

In Ireland, the recent census in 2016 reported that the number of children aged 6-16 years was 729,939 (available at: <https://www.dcy.gov.ie/documents/stateofthenationschildren/20170302SOTNCReport2016>). If an incidence rate of 1-3% is assumed for TDI in permanent dentition in schoolchildren (Oldin et al., 2015), approximately 7000- 22,000 children are likely to present with dental injuries each year.

1.1.3. Injury type and pattern

The presentation and type of dental injuries can vary widely. Various classification systems exist for TDI. In a systematic review of the literature, Feliciano and Caldas identified more than 50 different classification systems (Feliciano and Caldas, 2006). Andreasen developed the most comprehensive and universally accepted classification system containing categories of injuries to teeth, supporting structures, and gingiva and oral mucosa (Andreasen et al. 2013) (Appendix A).

Uncomplicated crown fractures are the most frequent type of injuries in the permanent dentition (Glendor et al., 1996; Bastone et al., 2000, Lam, 2016). When a single tooth is affected, it is often an upper central incisor (Petersson et al., 1996, Andreasen et al., 2013). However, quite frequently, multiple teeth are injured in trauma events (Glendor, 2008).

1.2. Treatment and outcome of TDI

The variable nature of dental trauma makes it difficult to accurately predict the prognosis of such injuries. Many factors can influence the post-injury course.

These can be generally divided as clinician-related, patient-related and injury-related factors.

Proper diagnosis, treatment and follow-up are essential clinical factors for favourable outcome. The International Association of Dental Traumatology (IADT) published a set of guidelines to help dentists make decisions for management (DiAngelis et al., 2012, Andersson et al., 2012). These guidelines are based on the best available evidence in the literature and on expert professional judgment.

The guidelines can be accessed on the following website <https://www.iadt-dentaltrauma.org/>. In addition, the Dental Trauma Guide uses the IADT guidelines and provides an evidence based treatment guide for certified members on the website <https://dentaltraumaguide.org/>. The Trauma Guide also provides prognostic information and predicts healing complications based on the various trauma entities for the individual case for all injury types. The Trauma Guide and the IADT guidelines help to raise the standard of care for all trauma patients worldwide.

With regard to injury-related factors, some injuries have less favourable outcome than others. Generally, the more severe the injury, the poorer the prognosis (Andreasen et al., 2013). Prognosis is also reduced in the presence of concurrent injuries (Lauridsen et al., 2012).

The age at which a child sustains a dental injury has been shown to affect tooth survival. The age reflects most importantly the stage of root development which determines the potential for revascularization and healing. Gender has no influence on healing. However, Andreasen et al. reported better healing outcomes in root-fractured incisors in girls and explained that by their tendency to sustain injuries at younger age compared to boys in the study (Andreasen et al., 2004).

This difference was not significant when gender was analysed against the various groups of root development. It is assumed that patient's cooperation and compliance with treatment are other factors that may also have an impact on treatment outcome. Very often, the dental visit following the trauma may be the first dental visit for that child. This can have implications on the child's anxiety and level of cooperation in the clinical setting.

Generally, TDI should be followed up regularly at least for 5 years after the injury as indicated in the IADT guidelines to minimise complications. In a study by Andreasen of 637 luxated teeth, only 27 (4%) (excluding intrusions) showed complete and spontaneous healing over a period of one year following the injury (Andreasen, 1986). This emphasized the need for vigilant and watchful monitoring of traumatised teeth.

Complications can arise rapidly (in few days or weeks) or gradually (over years) following dental trauma to permanent teeth in children. These often manifest as pulpal (e.g. loss of vitality) or periodontal sequelae (e.g. bone or root resorption). Other complications might manifest as aesthetic or malalignment issues which may require multidisciplinary management. Therefore, treatment of TDI may be complex, require extended treatment and reviews and is rarely finished before adulthood. Such treatment needs and complications can have emotional cost and quality of life implications. Over the last decade, there have been numerous reports on the dental trauma's impact on the quality of life in children (Bendo et al., 2010b, Damé-Teixeira et al., 2013a, Traebert et al., 2012, Ramos-Jorge et al., 2007, Porritt et al., 2011). Poorer oral health-related quality of life in the form of aesthetic complications, functional limitation, and negative impact on emotional and social aspects, has been reported following TDI.

1.3. Economic aspects of TDI

The scientific literature is rich in studies concerning TDI epidemiology, aetiology, classification and treatment. However, the monetary cost has been given very little attention. Only a few studies have addressed the resources spent in the management of TDI (Glendor et al., 2001, Wong and Kolokotsa, 2004, Nguyen et al., 2004, Borum and Andreasen, 2001). This is disappointing in view of the high prevalence figures mentioned previously.

As estimated previously, a number of 7,000- 22,000 children are likely to present each year with TDI in Ireland. The frequency of dental injuries to permanent teeth presents a public health problem, particularly due to their tendency to occur at a young age, the likely need for complicated and expensive treatment, and the time-consuming management that often continues into adulthood (Glendor, 2008). Management of children with new and existing TDI can impose a serious financial burden on the national healthcare system.

1.3.1. Previous studies on cost of TDI management

In a prospective study, Glendor et al. 2001 attempted to estimate the total societal costs of dental trauma in 192 Swedish children aged 1-17 years. In this study, injuries were grouped into uncomplicated (no displacement and no pulp exposure) and complicated (with displacement or pulp exposure) taking into account the increased risk of complications in the presence of pulp exposure or tooth dislocation. Injuries to permanent teeth were reported in 123 patients with 86 uncomplicated and 37 complicated injuries.

In the same study, indirect costs represented loss of production and loss of leisure time. Direct costs were defined as costs of health care service (including professional care, other labour, capital costs and supplies), cost of medicine, cost of loss of property and transport cost. The cost of health care service was estimated as an average fixed cost according to actual cost of health care services in Sweden in 1999. Other information was collected by telephone interviews with a range of 2-6 interviews over a period of 2 years (Glendor et al., 2001). It is assumed that data collected over the phone can be less reliable or truthful compared to data collected by other methods such as self-completed questionnaires.

The study showed that direct costs were dependent on the degree of severity of injury (complicated vs. uncomplicated) and reported that management of complicated injuries to permanent teeth were three times more expensive than management of uncomplicated injuries (Table 1.4).

Although the study provided valuable prospective estimate of the per-patient total cost of dental trauma, some issues could be identified in their costing methodology. Firstly, the authors reported the variables that were collected from dental records and phone surveys but did not clearly state the type of information that was sought over the phone. Furthermore, it is not clearly reported how soon these surveys were conducted after the visit. A potential for recall bias can be assumed if these interviews were not carried out straight after the visit particularly if the information collected was related to the costs incurred.

Transport costs were calculated only for the companions who used a private car or taxi. The cost was calculated based on the distance travelled. Although the use of private transport was the predominant mode (67%) of transport for patients in the

study, about one-third (33%) used public transport and this was considered at no cost. This method might have underestimated the travel cost.

Borum and Andreasen sought to analyse the economic implications of TDI in 7549 patients who had been treated at a major trauma centre in Denmark over 11-year period from 1972-1982. Similar to Glendor's study, TDI to primary and permanent teeth were included and grouped into complicated and uncomplicated injuries. In the study population injuries to permanent dentition occurred in 6980 teeth in 4675 patients (Borum and Andreasen, 2001). The study estimated a standard per-tooth treatment costs of \$926 and \$110 for complicated and uncomplicated injuries respectively in the permanent dentition (Table 1.3). However, the estimate involved population with a wide range of age (5-89 years) and cost was not presented specifically for the different age cohorts.

In the UK, Wong and Kolokotsa sought to retrospectively estimate the total costs of TDI treatment in children and adolescents (mean age 9.9 years) who attended a London teaching hospital between 1990 and 2001 (Wong and Kolokotsa, 2004). The inclusion criteria for this study included records of patients who had completed treatment for at least one injured permanent central incisor, and also those who were on annual review or active patients who attended 15 visits but treatment was incomplete. Eighty-one patients with 111 traumatised permanent incisors were included in the study. Thirty-six of the injuries were uncomplicated compared to 45 complicated injuries. Cost and number of visits were estimated for one trauma episode.

In their study, Wong and Kolokotsa limited direct costs to outpatient costs and indirect costs to missed working days. Direct outpatient costs were assigned according to the UK National Purchasing Unit in 1999/2000 (an average outpatient

cost of £65 per visit). For indirect costs (missed working hours), it was assumed that parent or carer would have to take a half-day off work to accompany the child for his/her dental visit. The half-day earning was estimated to be £42 based on 2000-year's figures (Wong and Kolokotsa, 2004). The mean number of visits was estimated to be 10.4 visits. However, it was not clearly stated whether this number occurred over one year or over the whole study period. Based on the median number of visits (8 visits), an average total cost of £856 was calculated per injured tooth per patient over the study period. However, this retrospective analysis was rather a rough estimation that did not account to the diverse trauma and patient factors. Some other flaws were identified in the costing methodology. The estimate only included the outpatient costs and cost of missed working hours. Other costs such as transport cost, cost of medicine and costs incurred outside the hospital were not included; therefore the total cost was underestimated. Another element for underestimation could be that treatment costs were calculated only up to the date of extraction, 9 (11%) of the teeth were extracted, and costs of any subsequent prosthetic replacement were not included. In addition, the study assumed that all parents were working and did not report the proportion of non-working companions.

Table 1.3 summarises the estimated average treatment cost for complicated and uncomplicated injuries in permanent teeth, as derived from the previously mentioned studies. From the table, it is clear that TDI management can impose obvious demand on healthcare systems.

Table 1.3: Summary of estimated average treatment cost in **US\$** to complicated and uncomplicated injuries in permanent teeth (reproduced from (Andreasen et al., 2013))

Study	Country	Uncomplicated	Complicated	
Glendor et al. 2001	Sweden	200	606	Per patient over 2 years
Borum and Andreasen 2001	Denmark	110	926	Per tooth over 12 years
Wong and Kolokosta 2004	UK	858		Per tooth over 12 years

A Canadian study aimed to describe the economic burden of replanting avulsed permanent incisors over the first year after injury (Nguyen et al., 2004). Clinical records of all patients who attended the Hospital for Sick Children in Toronto for replantation between 1988 to 1999 were reviewed. Complete charts of forty-three patients with 60 avulsed teeth were included. The burden was calculated up to the time of extraction and included the cost of initial prosthetic replacement. Twenty-three patients had 31 incisors extracted over the study period. However, only 11 teeth in six patients were extracted during the first year after the avulsion. Costs of the treatment provided were assigned according to the Ontario Dental Association (ODA) Suggested Fee Guide for General Practitioners in 2000 and included cost of emergency visit radiographs, endodontic treatment, extraction, speciality

consultation and the cost of initial prosthetic replacement. The authors estimated a mean treatment cost of \$1465 CAD per patient during the first year post-trauma (Nguyen et al., 2004). However, the study presented treatment costs only for avulsed incisors . Furthermore, the number of replanted teeth per patient was not addressed in the cost.

It is worth mentioning that different studies used different methodologies for costs estimation. Table 1.4 summarises the costing methodology for the above-mentioned studies. To our knowledge, apart from the Glendor et al. study in 2001, no study in the literature has comprehensively and prospectively measured all costs (direct and indirect) related to TDI in children and adolescents. However, Glendor's study had some limitations related to data collection as mentioned previously and the data was collected more than 15 years ago, before IADT guidelines were introduced in 2001. These guidelines have standardized the post-injury care in terms of the acute management and review visits and these would subsequently impact on the cost. The last update of the IADT guidelines was issued in 2012 (DiAngelis et al., 2012, Andersson et al., 2012).

Table1.4: Summary of previous research on TDI cost								
Study	Country	Sample (permanent teeth)	Age (years)	Study design and material	Cost collected	Estimated treatment cost	Estimated total cost	Study period
Glendor et al. 2001	Sweden	123 pt * 86 UC 37 C	6-17	Prospective Average healthcare service cost from the Federation of County Councils Phone surveys for other costs	Direct costs: cost of healthcare service (labour, capitals and supplies) cost of medicine, cost of loss of property and transport cost Indirect costs: Cost of loss of production and loss of leisure time	Per-patient* cost =1834 SEK for UC & 5557 SEK for C	Per-patient* cost =5734 SEK for C & 1889 SEK for UC	2-year
Borum & Andreasen 2001	Denmark	4675 pt 6356 UC 4317 C	5-82	Retrospective Records of patients with TDI (1972-1982)	Cost of treatment (procedure)	Per-tooth cost = \$110 for UC & \$926 for C	-----	11-year
Wong & Kolokotsa 2004	UK	81 pt 36 UC 45 C	7-18	Retrospective Records of patients with TDI (1990-2001)	Direct costs: outpatient cost Indirect costs: missed working hours	Per-tooth cost = £520	Per-tooth cost = £856	12-year
Nyguen et al. 2004	Canada	43 pt* 60 incisors	7-18	Retrospective Records of patients with avulsion (1988-1999)	Treatment cost (including radiographs)	Per-patient* cost = \$1465 CAD	-----	1-year (the first year post- avulsion)
Abbreviations: pt: patient; UC : uncomplicated; C: complicated * could have more than one injured tooth								

1.3.2. Previous studies on time spent on TDI management

1.3.2.1. Factors influencing the treatment time

Management of TDI is time-consuming and involves many visits, particularly in the first year post injury in children. The total time spent can be divided into direct (clinical) and indirect (non-clinical) time.

The IADT guidelines have somewhat standardised the number of visits required for successful management of TDI. However, the treatment time and number of visits can vary according to a number of factors.

The degree of injury severity was found to have a major influence, with more time needed to manage more complicated injuries. Glendor et al. reported a total direct (clinical) time of 4.7 and 1.8 hours required to manage complicated and uncomplicated injuries in the permanent dentition over a period of 2 years (Glendor et al., 2000a).

The type of dentition also had a great impact on the clinical time. Unlike primary teeth, frequent and lengthy recall visits are often needed for injured permanent teeth (Glendor et al., 1998).

The type of injury is likely another contributing factor in determining the time required. Borssén et al. found that the time spent in the management of TDI varied with the injury type. In his study, complicated crown fractures and crown-root fractures required longer treatment time compared to uncomplicated crown fracture. The time significantly increased in the presence of concomitant luxation injury (Borssén et al., 2002).

Teeth treated by a specialist needed more time, which probably indicates more complex injuries (Glendor et al., 1998, Borssén et al., 2002).

Injuries in children aged 11 and less were found to require increased treatment time due to the presence of an immature roots that may complicate and elongate treatment (Borssén et al., 2002). In addition, there is increased risk of sustaining multiple injuries if the first trauma occurred before the age of 11, which can also contribute to increased subsequent cost and time (Glendor et al., 2000a). It is also assumed that younger patients may present more behavioural issues and therefore require extended treatment time.

Immediate referral and presentation of dental injuries, and number of injured teeth are other reported factors that may affect the treatment time (Glendor et al., 1998, Glendor et al., 2000a, Borssén et al., 2002)

Location of the clinic or access to dental care was found to influence the transport and total time but not the treatment time (Borssén et al., 2002).

1.3.2.2. Estimated number of visits

Different studies reported varying number of visits required to manage dental injuries. A longitudinal and retrospective study of a random sample of 106 children and adolescents in Denmark estimated that 9.2 visits were required for the uncomplicated injuries in the permanent dentition compared to 16.4 visits for complicated injuries over the study period (1972-1988) (Glendor et al., 1998). In the same study, Glendor also reported the average number of visits required in the first year following the injury was 6.2 and 11.9 visits per patient for the management of uncomplicated and complicated injuries respectively in the

permanent dentition. The authors concluded that the majority of visits often take place in the first year following the injury (Glendor et al., 1998). This finding was also reported in another study (Nguyen et al., 2004) and it is supported by the current IADT recommendations.

Glendor et al. carried out another study to estimate the number of visits prospectively over a 2-year period (1992-1993) (Glendor et al., 2000a). A number of 4.1 and 8.9 visits was estimated for uncomplicated and complicated injuries in the permanent dentition over the study period. The number of visits in this 2-year prospective study was less compared to the above-mentioned retrospective report (Glendor et al., 1998). The difference is likely due to the prospective nature of data collection in the 2-year study which could have resulted in a more accurate estimation.

Many other studies (Al-Jundi, 2004, Nguyen et al., 2004, Wong and Kolokotsa, 2004, Glendor et al., 2000a) in the literature reported variable ranges of number of visits (Table 1.5). These studies did not differentiate between complicated and uncomplicated injuries and these studies are not readily comparable also due to the variation in follow up duration.

It is noteworthy to mention that these studies were carried out before the development of the IADT guidelines. Since the last update of these guidelines, only one retrospective study investigated the number of visits required following TDI. This study was carried out at Leeds Dental Institute and involved 100 patients with 186 injured permanent teeth who had been treated at the hospital between 2003- 2007. A median number of 6 visits was required per tooth with a range of 1- 22 visits(Keasberry et al., 2013). Although teeth were grouped into complicated and uncomplicated injuries in the study, the authors did not differentiate between the number of visits required for each category. In addition, the authors did not report the time period over which this number of visits was required. Also, it was not mentioned whether or not the IADT guidelines were followed for treatment and review protocol in the study population.

Table 1.5: Summary of estimated number of visits following TDI in the permanent dentition

Study	Country	Sample	Age (years)	Study design	Average number of visits (range)	Study period
Glendor et al. 1998	Sweden	82 pt 245 teeth	7-18	Retrospective	U : 9.2(1-27) C: 16.4(1-24) Per pt	12yr
Glendor et al. 2000	Sweden	123 pt	1-17	Prospective	U: 4.1 (1-27) C: 8.9 (1-26) Per pt	2 yr
Borssén, Källestal et al. 2002)	Sweden	575 teeth	7-16	Retrospective	4.1 (1-41) Per pt	15 yr
Wong & Kolokotsa 2004	London, UK	81 pt (111 incisors)	6-18	Retrospective	10.4(3-27) Per tooth	12 yr
Al-Jundi 2004	Jordan	195 pt (287 teeth)	NR	Retrospective	NR (3-17.2) Per NR	1-3 yr
Nguyen et al. 2004	Canada	43 pt (60 incisors)	7-18	Retrospective	9.1 (4-15) Per pt	1 yr
Keasberry et al. 2013	Leeds, UK	100 pt (186 teeth)	5-16	Retrospective	NR (1-22) Per tooth	≤4 yr
Abbreviations : pt : patient ; U: uncomplicated ; C: complicated ; yr : year ; NR: not reported						

In conclusion, there is lack of prospective data on the time and number of visits spent on TDI management since the introduction of the IADT guidelines. These international guidelines have standardised the post-injury care and stated that 2-5 review visits are required in the first year depending on the type of injury (Appendix L).

Overall, many studies suggest that treatment of dental injuries to permanent teeth is often costly and time-consuming. Since the introduction of the IADT guidelines, this is the first prospective study to investigate the total cost and the number of visits required for the management of TDI to permanent teeth in children in a specialised trauma clinic in Ireland.

CHAPTER TWO: MATERIALS AND METHODS

2.1. Ethical approval

The study was approved by the Dental School Ethics Committee, Dublin, Ireland (Appendix B) for cost estimation of dental injuries in children

2.2. Aim

The purpose of this study was to estimate the cost of dental trauma based on injuries to the permanent dentition in children aged 6-16 years treated at the Dublin Dental University Hospital (DDUH).

2.3. Objectives

1. To estimate the total direct and indirect costs of injuries to permanent teeth in children and adolescents over one year.
2. To investigate association between type of injury (complicated vs. uncomplicated) and total cost.
3. To investigate association between date of injury (injuries in the first year vs. older injuries) and total cost.
4. To investigate influence other variables such as age and gender on total costs.
5. To estimate the total number of visits required for management of injuries to permanent teeth in children and adolescents in one year.

2.4. The overall study design

The study was prospective in design involving children with old and new injuries to their permanent teeth. The study was intended to estimate the total cost and time spent in treatment of dental injuries over a period of one year within the DDUH. The IADT guidelines were used as guidance for the management of TDI in children. Hospital based costs were used to estimate the direct cost of dental treatment. Indirect costs were estimated from self-completed questionnaires at each visit.

2.5. Study population

The sample population comprised children age 6-16 years, attending DDUH following trauma to their permanent teeth.

2.5.1. Power calculation

Power calculation was undertaken based on two previous studies (Glendor et al., 2001, Wong and Kolokotsa, 2004). It was estimated that a sample size of 122 and 98 would be needed to achieve a power of 90% and 80% respectively (Appendix C).

2.5.2. Inclusion and exclusion criteria

Only children who fulfilled the inclusion criteria and whose parents consented were enrolled in the study. Criteria for inclusion and exclusion are listed in Table 2.1.

Table 2.1: Inclusion and exclusion criteria for study population

Inclusion criteria
• Children aged 6-16 years • Medically ASA I or II (healthy patients or mildly sick who can be seen in an outpatient setting with little or no modification to their dental care) • Injuries to permanent incisors only • Children who are reviewed at DDUH
Exclusion criteria
• Patients with incomplete records (missing clinical notes of at least one visit) • Irregular attendees (missing more than 3 appointments) • Patients with poor cooperation for dental intervention (definitively negative behaviour according to Frankl scale in 3 or more visits) • Patients managed by undergraduate students (as appointments are often longer with training dental students) • Patients with multiple significant trauma episodes

2.5.3. Recruitment and sampling

All children who fulfilled the abovementioned inclusion criteria were consecutively enrolled in the study. The recruitment pathway is illustrated in Figure 2.1. Children were included regardless of their injury type, severity or date of injury. No randomisation was carried out and a convenience sample was collected.

2.6. Consent and assent

Children with TDI were identified. An invitation letter (Appendix D) along with information leaflet (Appendix E) was mailed by post to potential participants one week before their scheduled appointment. On the day of their child's appointment, parents were approached by an appointed gatekeeper to assess willingness to participate in the study. Parents were asked to sign a consent form (Appendix F) if they were happy to participate. Assent forms were signed by children who were 10 years of age or older (Appendix G).

2.7. Workflow

The study was conducted in two parts at DDUH. Patients were enrolled in two ways; existing patients in Trauma Clinic and new patients through the Accident and Emergency (A&E) Department.

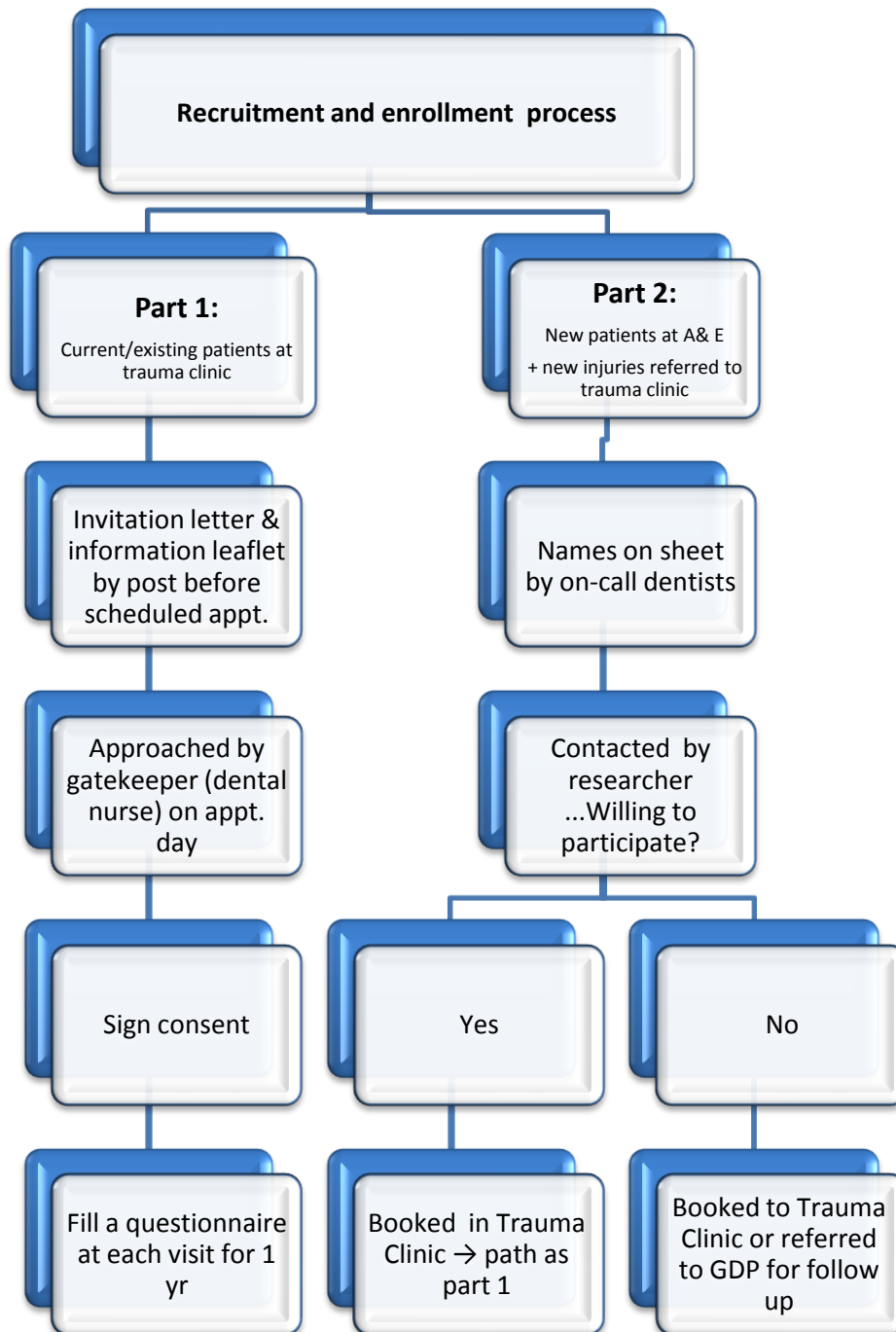


Figure 2.1: Recruitment and enrollment pathway

Abbreviations: Appt.: appointment, Yr: year, GDP: General Dental Practitioner

2.7.1. Part I: Existing patients

Children who had suffered TDI and were attending Trauma Clinic at DDUH were selected. These patients were at various stages of treatment or on review. To assess any correlation between injury date and cost or number of visits, patients were divided according to the date of injury into:

1. Injuries within the first year
2. Injuries in their second or third year of management
3. Injuries in fourth year of management and older

On each day of their child's appointment, parents were requested to fill in a questionnaire about the overall cost of their visit for that day.

A convenience sample of patients was consecutively enrolled for 8 months (September 2015 to April 2016).

2.7.2. Part II: New patients

Parents of children and adolescents attending the A&E department due to recent dental trauma were invited to participate in the study. Due to the stress and anxiety involved in the trauma accident, it was deemed impractical and inappropriate to enroll patients on the day of their emergency visit. Instead, the emergency dentists recorded the names of potential participants on a sheet made available by the investigator at the triage unit. Parents of eligible patients were contacted by the researcher within one week to be informed about the study. Parents who were willing to take part in the research were sent an information leaflet and a consent form by post. On the first appointment (often within 2 weeks) following their child's emergency visit, parents were asked to complete a

questionnaire similar to Part I participants. Parents were also given a second form of the questionnaire to fill in regarding the cost of their emergency visit.

Patients referred to the Trauma Clinic were also considered for inclusion in Part II (i.e. new injuries) provided that children had had only emergency treatment completed by their local dentist and that their injury was not older than 3 months.

Subsequently, as in Part I, parents were requested to complete the questionnaire at each follow-up visit. A convenience sample of patients was consecutively collected from September 2015 to May 2016.

In either part, data were prospectively collected from self-completed questionnaires at each visit over a period of one year.

2.8. Questionnaire

A 10-item questionnaire (Appendix H) was completed by parents and recorded information about any out-of-pocket expenses related to child's dental visit.

2.8.1. Questions generation and piloting

A questionnaire based on the most commonly incurred costs by parents of children with dental injuries was prepared by the investigator and not based on earlier published work. The questionnaire sought information about the overall cost of the dental visit; mode of travel, cost and time, appointment time (including waiting time), childcare cost, missed working hours, medication cost, cost of devices or appliances needed following the injury e.g. sportsguard, cost of dental care sought elsewhere, and any other incurred costs.

The questionnaire was piloted in 15 patients. Only minor changes had to be made to make questions clearer and more understandable. The final questionnaire was used for all patients in the study.

2.8.2. Data confidentiality

Each patient's hospital number was completed on the top of each questionnaire as a reference number before handing in it to the parent of the child attending the visit. Candidates were not requested to write their names or any other identifier on the questionnaire. All questionnaires were returned at the end of dental visit and stored in a locked cabinet in an electronically-locked room at the hospital. Consent forms and questionnaires were only accessible to the principal investigator and the thesis supervisor.

2.9. Data from patients' records

The following data were extracted from computerised patients' records (Salud Dental Suite version 1.17.0, Two-ten Health Ltd, Dublin, Republic of Ireland): hospital number, date of birth, gender, address (only used for travel distance estimation), injury group (complicated vs. uncomplicated), injury types or diagnoses, date of injury, date of first visit, and any hospital admission or stays due to the injury. Furthermore, data related to each individual visit such as the type of treatment, number of radiographs, laboratory fees, and operator level of training were also recorded (Appendix I).

2.9.1. *Data confidentiality*

All data were transferred to Excel spread sheets and stored in a password-protected computer which was only accessible to the principal investigator and the thesis supervisor.

2.10. Classifications of injuries

For the purpose of this study, traumatic injuries to the permanent teeth were broadly classified into complicated and uncomplicated injuries as the following:

- ***Uncomplicated trauma***: no pulpal tissue exposure (infracture, uncomplicated crown fracture, and uncomplicated crown-root fracture) and no dislocation of the tooth (concussion and subluxation).
- ***Complicated trauma***: exposure of pulpal tissue (complicated crown fracture, and complicated crown-root fracture and root fracture) and/or dislocation of the tooth (intrusion, extrusion, lateral luxation and exarticulation).

This level of classification was first defined by Glendor et al. [1996] for the purpose of estimating the economic consequences of dental injuries in the community. This classification was later adopted in other studies (Borum and Andreasen 2001; Borssén et al., 2002; Wong and Kolokosta 2004; Keasberry et al., 2013) with little or no modification.

2.10.1. *Injuries types (diagnoses)*

In addition to the broad classification mentioned above, trauma types (diagnoses) were recorded according to Andreasen's classification (Andreasen et al. 2013) (Appendix A).

2.10.2. *Issues in classification*

Several issues arose when classifying injuries and selecting an index tooth for cost analysis; these are summarized in the following section:

2.10.2.1. Multiple injured teeth in one patient

Glendor et al. indicated that the most severe diagnosis often determines treatment cost and time (Glendor, 2000). Therefore, in the current work, when a patient presented with multiple injured teeth, the tooth with the most complicated injury was chosen for cost and time analysis. A severity index (Table 2.2) was devised by the authors to help select the most severely injured tooth for cost estimation. This severity rank is not evidence-based and had to be developed to help in data categorisation.

When two teeth sustained similar extent of injury (e.g. two avulsed teeth or two complicated crown fractures), only one tooth was randomly selected to determine treatment costs.

Table 2.2: Severity index for complicated injuries

Severity rank for complicated injuries	
 Most severe	1. Root fracture
	2. Complicated crown fracture
	3. Complicated crown-root fracture
	4. Palatal luxation/ extrusion
	5. Intrusion
	6. Avulsion

2.10.2.2. A tooth with several diagnoses

2.10.2.2.1. A tooth with uncomplicated and complicated injuries

The most severe diagnosis was chosen. In other words; a tooth with complicated and uncomplicated trauma was recorded as having a complicated injury, a method previously used by Glendor et al. (Glendor, 2000).

2.10.2.2.2. A tooth with more than one complicated injury

When a tooth presented with clear multiple complicated injuries e.g. intrusion and complicated crown fracture, the devised severity index (Table 2.2) was also used here to give a diagnosis for the tooth.

2.10.2.2.3. *A tooth with more than one uncomplicated injury*

No attempt was made to differentiate between single or multiple uncomplicated injuries in one tooth. This means that when a tooth presented with several uncomplicated injuries (uncomplicated crown fracture, concussion or subluxation) it was classified as uncomplicated injury. This is because injuries like concussion or subluxation may sometimes go unnoticed or unreported.

2.10.2.3. Multiple trauma episodes

Children who had had multiple trauma episodes were excluded as it was difficult to determine the relative severity of different events. Furthermore, it is assumed that additional traumas often lead to more complications and subsequently increased treatment time and cost.

2.11. Operators expertise

Patients in Trauma Clinic were seen by a team of operators with different levels of clinical expertise (general dentists, postgraduate students, and specialists). However, all operators were trained to use most up-to-date IADT guidelines for diagnosis, treatment and follow up and all patients were ultimately seen by the paediatric consultant in the clinic. The dentists within the emergency service were also trained to use the IADT guidelines for diagnosis and acute management of dental injuries.

2.12. Costing methodology

2.12.1. Costs classification

In the present study, costs were defined as the following (Table 2.3):

- **Direct costs:** represent what is paid by patients and by the hospital for a dental visit. These comprised the cost of health care service including capital and overheads, operator and nursing staff costs, cost of the in-patient and out-patient treatment, pharmaceutical interventions, radiographic investigations, and laboratory fees.
- **Indirect costs:** The most frequently incurred costs; travel cost, childcare cost, and cost of missing working hours, were measured.

Intangible costs such as emotional aspects of TDI and their impact on the quality of life of the child, parents and family were not addressed in this work. These are difficult to quantify and need specific tools for assessment.

Table 2.3: Costs classification

Direct costs
• Capitals and overheads • Clinical costs(operator/ nursing cost + treatment cost+ radiographs) • Laboratory fees • Medications • In-patient costs
Indirect costs
• Travel costs • Childcare • Production loss

2.12.2. Costs determination

The tooth with the most severe injury per patient was chosen for cost estimation. In all instances, costs were recorded in monetary values and calculated for one injured tooth per patient in one year.

2.12.3. Valuation of direct costs

- **Capitals and overhead cost:** Using pay and non-pay expenditure, the Finance Department at DDUH has developed an average unit cost per patient. This value was adjusted for inflation for the year 2016 and applied for all patients regardless of length of their dental visit or their insurance status.
- **Operator and nursing staff cost:** This cost was calculated based on the treatment time.
 - **Treatment time estimation:** The treatment time was defined as the time required to complete a defined procedure. This is different from the appointment time mentioned in the questionnaire in that treatment time represents the net clinical time of the dental visit and does not include the waiting time. Treatment time was documented for a random set of patients and registered for the different operators in Trauma Clinic. Calculation of treatment time was repeatedly recorded on 10 different occasions for each of category of clinician (e.g. general dentists, postgraduate students, and specialists) and an average range of time was ultimately calculated. Table 2.4 lists the estimated treatment time for the commonly performed procedures in Trauma Clinic.

Table 2.4: Treatment time for the most commonly performed procedures in Trauma Clinic

Procedure	Treatment time in minutes Average (range)	Procedure	Treatment time in minutes Average (range)
Assessment	45 (40-60)	Composite	50 (45-60)
Consultation / joint planning	50 (45-70)	First stage RCT	55 (45-60)
Review	20 (15-30)	CaOH change	35 (30-45)
Sportguard fit	15 (10-20)	MTA/obturation	100 (90-120)
Radiograph	7 (5-15)	Extraction /PD	50 (45-60)

The operator cost per visit was calculated by multiplying the operator's hourly rate by the treatment time. The hourly rate of pay for each category of clinician (e.g. postgraduate student, general dental surgeon, and specialists or consultants) was made available from the Finance Department data at DDUH for year 2016 (Table 2.5).

Table 2.5 : Hourly rate (€) for clinician and nursing staff

Category	Hourly rate (€)
Junior staff /general dentist	22.77
Postgraduate student	22.77
Specialist	64.35
Consultant	92.30
Dental nurse	18.01

Similar costing method was followed to calculate the cost of the supporting nursing staff. The hourly rate of a senior nurse was also obtained from the Finance Department. Assuming availability of one dental nurse for each clinician, the nursing support cost per patient was calculated by multiplying the hourly rate for the nurse by the treatment time.

- **Treatment costs and laboratory fees:** Treatment costs for the most severely injured tooth were assigned using the official most up-to-date price list for patients at DDUH (Table 2.6). Likewise, the cost of the most commonly required laboratory work were assigned using the DDUH most up-to-date price list.
- **Radiographs cost:** The DDUH cost for a radiograph was multiplied by the number of radiographs obtained. As mentioned previously, only radiographs taken for the traumatised tooth that was chosen for cost analysis were recorded.
- **Medications cost:** If children had to take medications related to their dental injury, the type or name of the medication was sought and a cost was assigned according to the Monthly Index of Medical Specialties (MIMS, June 2017). Prescription fees were not included.
- **Hospital admission cost:** The average cost for the management of dental patients as a day case under General Anaesthesia (GA) was estimated to be €689 based on a recent retrospective analysis in Cork, Ireland (McAuliffe et al., 2017). The total hospital cost included the cost of the GA (€689) added to the cost of dental treatment, radiographs and laboratory costs. Due to complexity of hospital settings, operator and nursing costs were not included and assumed to be part of the overall service cost,

Table 2.6: Price list for the commonly provided clinical and laboratory procedures in Trauma Clinic

Treatment	DDUH Cost (€)	Treatment	DDUH Cost (€)
Emergency visit*	75	Extraction	55
Assessment	65	Surgical extraction	150
Review	35	Decoronation	180
Radiograph	20	Vital/non-vital bleaching	250
Composite	65	Spoon denture(1 tooth)	110
Repair of existing restoration (no charge within 1 year)	45	Study casts	50
RCT (conventional)	300	Removable orthodontic appliance per arch	575
Apexification	115	Fixed appliance per arch	1245
Apexification follow up	15	Removable/fixed appliance replace	65
MTA/obtura	60	Removable/fixed appliance repair	25
Sportguard	75	Sectional fixed per arch	230
* Emergency visit may include glass ionomer restorations, Cvek pulpotomy and splinting.			
* Emergency pulp extirpation is included with the RCT cost			

2.12.4. Valuation of indirect costs

Indirect costs were identified as the non-clinical out-of-pocket expenses paid by patients. Participants were asked to indicate these costs in the questionnaire at each visit.

- **Travel cost:** Parents were asked to indicate the mode of transport and the approximate total travel time in the questionnaire. The cost of public transport was recorded as indicated in the individual questionnaire. For those who did not indicate or those who travelled by private car, the distance in kilometres from home address to DDUH was calculated using Google maps distance calculator (available at: <https://www.daftlogic.com/projects-google-maps-distance-calculator.htm>) and travel cost was calculated by multiplying the distance by the government-approved mileage rate in Ireland (available at: www.revenue.ie). A medium-sized car with engine capacity 1200 to 1500cc was assumed as a transport vehicle and a rate was assigned accordingly. The calculated cost was multiplied by two to get the cost for the return journey.
- **Childcare cost:** Parents were asked to indicate whether or not a childcare cost was incurred. Whenever a childcare cost was incurred, parents were asked to report the cost per hour. The total childcare cost was then estimated by multiplying the indicated hourly cost by the total time (appointment time and total travel time).
- **Cost of loss of production (missed working hours):** Parents were asked to indicate whether or not they missed working hours to accompany their child to his or her appointment. However, they were not asked to indicate their occupation or income.

For working parents, the cost of missing working hours was estimated in monetary values by multiplying the average hourly earnings by the total time (appointment time and total travel time). The average hourly earnings was obtained from the Central Statistics Office, Ireland (available at <http://www.cso.ie/en/statistics/earnings/>)

All aforementioned costs were calculated for each patient at each visit. The costs of all visits in one year were added up to achieve a total annual cost for each patient.

2.13. Statistical analysis

All data were transferred to a Microsoft Excel spreadsheet. The statistical software package R commander (version 3.3.3) (available at: www.rcommander.com) was used for analysis. A simple independent t-test was used for simple comparisons of the mean total costs between the different groups. A linear regression model was used to investigate the relationship between the average annual total cost and the different variables.

2.13.1. Model evaluation

As the original data set did not fit the linear regression model (Appendix J) and the assumption of constant variance was violated, data transformation was considered. Transformation was carried out by taking the logarithm (log) of the total cost. The log-transformed data were analysed by using the software package R (www.cran.r-project.org/).

Both assumption of normality and assumption of constant variance were satisfied by the transformation. Detailed statistical analysis can be found in Appendix J.

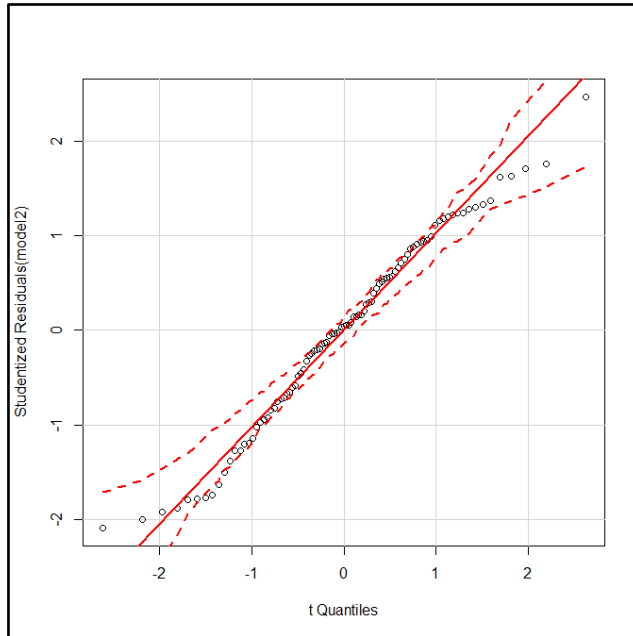


Figure 2.2: Q-Q plot shows assumption of normality is satisfied. The plot should produce an approximately straight line if the points come from a normal distribution.

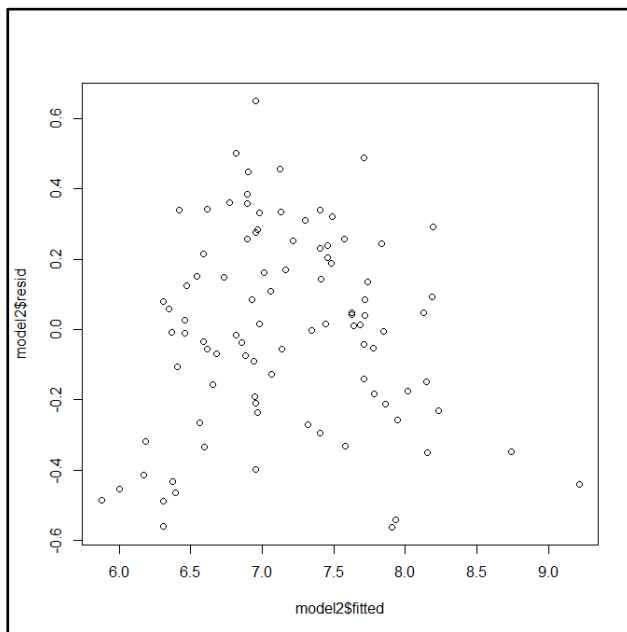


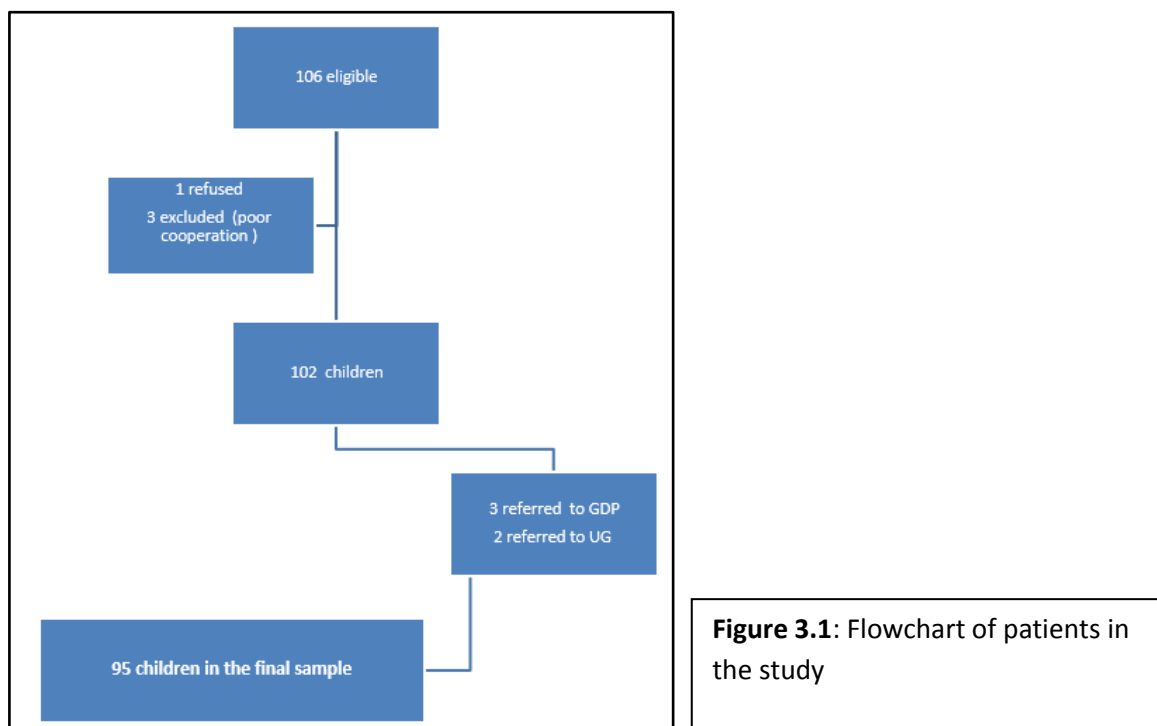
Figure 2.3: Plot of residuals vs. fitted values shows that the assumption of constant variance is satisfied. Plotting residuals versus the value of a fitted response should produce a distribution of points scattered randomly with no visible pattern, which means the errors have constant variance.

CHAPTER THREE: RESULTS

3.1. Descriptive and t-test statistics

3.1.1. Age and gender distribution in the study population

One hundred and four patients were consecutively enrolled from September 2015 to May 2016. Nine participants were excluded or dropped out over the study period (Figure 3.1). However, the estimated 80% power was almost achieved with the final sample. Ninety-five children were included in the statistical analysis.



The study sample consisted of 60 (63.2%) males and 35 (36.8%) females (Figure 3.2). Participants' age ranged from 6 to 16 years (mean = 10.5, SD =2.5). Sixty-six (69.5%) patients were under the age of 11 years and 29 (30.5%) were 11 years or older (Figure3.3).

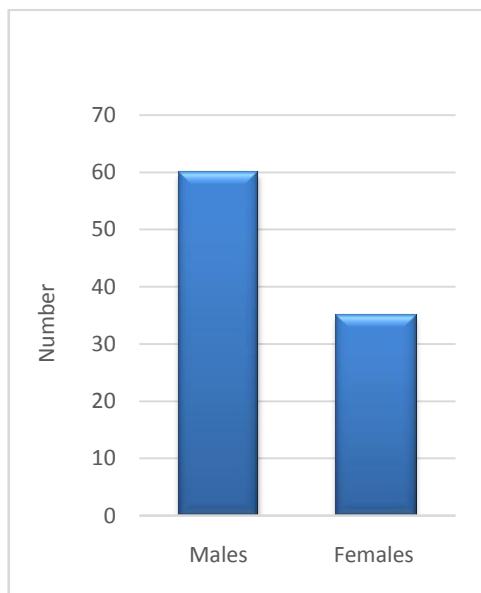


Figure 3.2: Gender distribution in the study sample

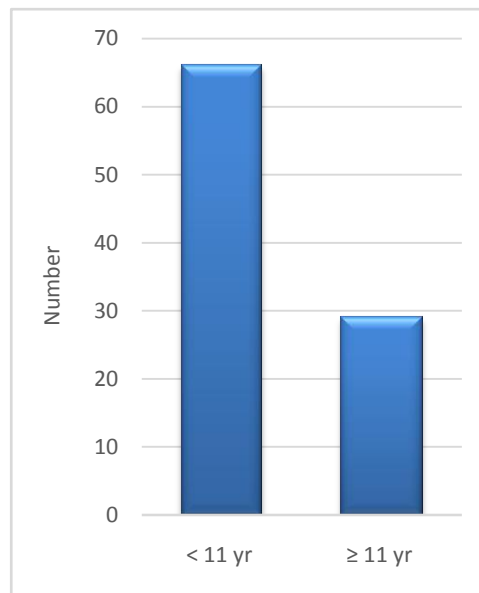


Figure 3.3: Distribution of age groups in the study sample

3.1.2. Classification of injuries

3.1.2.1. Injury group and type

The tooth with the most severe injury was recorded per patient. The majority of the injuries (77.9%) were complicated compared to (22.1%) in the uncomplicated group. Table 3.1 show the various injuries types in the final sample.

Table 3.1: Frequency of the various injury types

Injury group	Injury types	Frequency (%)
Uncomplicated	1. Uncomplicated crown fracture	21(22.1%)
Complicated	2. Complicated crown fracture	19(20.0%)
	3. Root fracture	4 (4.2%)
	4. Crown-root fracture	1(1.1%)
	5. Lateral luxation/extrusion	14(14.7%)
	6. Intrusion	7(7.4%)
	7. Avulsion	25 (26.3%)
	8. More than one complicated injury in the same tooth	4 (4.2%)

3.1.2.2. Injury date

Fifty-one (53.7%) of the injuries had occurred within the first year, 25 (26.3%) were in the second or third year of follow up and 19 (20.0%) were older than 4 years (Figure 3.4).

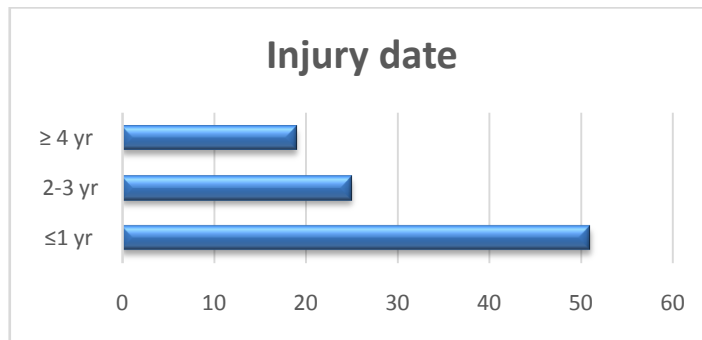


Figure 3.4: Distribution of injuries by date

Table 3.2: Distribution of injuries by group and date

Time since injury date	Uncomplicated	Complicated	Total
≤1 yr	11	40	51
2 – 3 yr	7	18	25
≥ 4 yr	3	16	19
Total	21	72	95

3.1.3. Need for hospital admission

The majority of the study population had their dental injury managed in Trauma Clinic. Only 3 patients required hospital admission for treatment under GA during the study period (Table 3.3). However retrospective analysis of the patients records revealed that 8 (7.7%) patients required GA at some stage of their dental trauma management. The reason for using GA was mainly due to child's inability to cooperate with a complex procedure which was surgical repositioning of severely intruded teeth (3 cases) and decoronation (5 cases). For surgical repositioning, GA was required soon after the injury, i.e. within the first year, whereas timing of decoronation was more varied.

Table 3.3: The need for GA for injuries management in the study population

Need for GA over the study period	Count (percentage)
GA required	3 (3.16%)
No GA required	92 (96.84%)

3.1.4. Distance travelled

The distance travelled by patients to attend the hospital for care was calculated for every child from their home address to the DDUH using Google maps at (<https://www.google.ie/maps>). The mean distance travelled was 29.5 km. Table 3.4 shows the distribution of the travel distance in the study population.

Table 3.4: Distribution of the travel distance in the study population

Distance travelled (Km)	Count (percentage)
< 25	58 (61.05%)
25-50	17 (17.89%)
50-75	13 (13.68%)
75-100	3 (3.16%)
>100	4 (4.21%)

3.1.5. Number of visits

The mean number of visits required over the study period (one year) was 5.4 with a range of 1-14 visits. Interestingly, there was no significant difference (p -value=0.24) in the number of visits required for complicated (5.6 visits) and uncomplicated (4.9 visits) injuries in one year (Figure 3.5). It was estimated that the mean number of visits required over one-year period was 6.1 visits for injuries in the first year, 5.5 visits for injuries in the second or third year and 3.6 visits are for injuries in the fourth year and older (Figure 3.6).

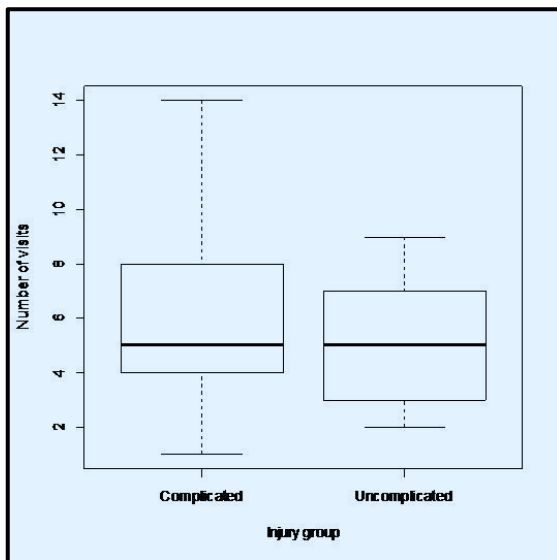


Figure 3.5: The number of visits for complicated and uncomplicated injuries in the entire sample

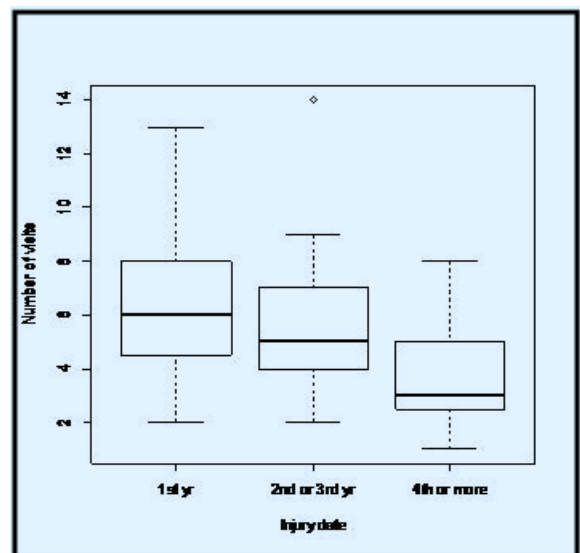


Figure 3.6: The number of visits for all injuries duration in the entire sample.

However, when the number of visits was analysed for new injuries in the first year only, statistically significant difference was noted between the two injury groups (p-value=0.01). Complicated injuries required 6.6 visits compared to 4.4 visits for uncomplicated injuries during the first year (Figure 3.7).

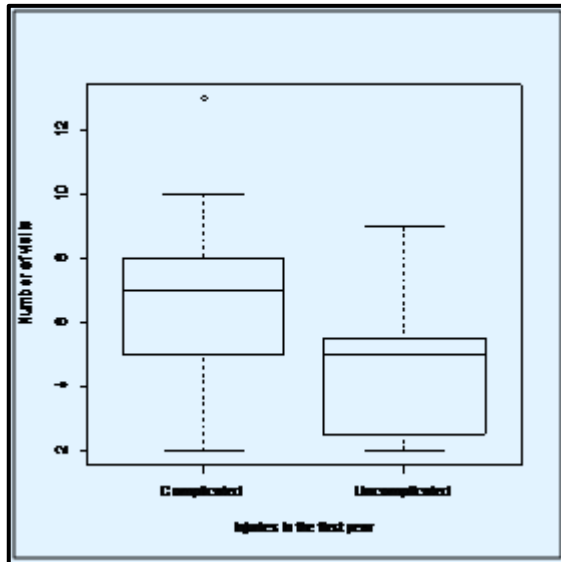


Figure 3.7: The number of visits for complicated and uncomplicated injuries in the first year.

Age and gender had no statistically significant influence on the number of visits as shown in Table 3.5.

Table 3.5: The number of visits as analysed by gender and age groups over the study period

Variable	Average number of visits	*P-value
Gender		
Males	5.3	0.49
Females	5.7	
Age		
<11 years	5.6	0.64
≥ 11 years	5.3	
*Simple independent t-test		

3.1.6. Direct costs

Direct costs included capital/overhead costs, cost of operator and nursing staff, treatment and radiographs costs, laboratory fees, cost of medications and hospitalisation costs. The methods used for allocating costs were described previously.

A fixed unit cost of €49.22 was obtained from the Finance Department at DDUH as a cost for capital and overheads per patient per visit. The hourly pay rate for each category of clinician and nursing staff was also made available from the Finance Department at the DDUH (Table 2.5). Labour (operator and nursing staff) cost per patient per visit was calculated by multiplying this hourly rate by the previously estimated treatment time (Table 2.4).

Treatment including radiographs costs and lab fees were assigned according to the price list at DDUH (Table 2.5). Additional services such as orthodontic treatment or GA were assigned a standard fee as described previously. Medications cost per individual were recorded as they were incurred.

In the study population, 21/95 (22.1%) had a medical card (a kind of health insurance in Ireland) that entitled them to free dental care and 42/95 (44.2%) were covered by accidents insurance or other forms of dental insurance. However, the cost of the treatment provided was recorded at each visit regardless of the source funding.

Direct costs per patient were recorded prospectively at each visit for a one-year period. Age and gender did not significantly influence the average annual direct costs as shown in Table 3.6.

Table 3.6: The mean annual direct costs (€) as analysed by gender and age groups

Variable	Direct costs (€)	*P-value
Gender		
Males	1212 (SD=792)	0.84
Females	1182 (SD=655)	
Age		
<11 yr	1240 (SD=710)	0.46
≥11 yr	1111 (SD=812)	
*Simple independent t-test		

The average annual direct cost was €1257.7 (SD=776.4) and €1000.4 (SD=570.7) for complicated and uncomplicated injuries respectively with no statistically significant difference (p-value=0.10).

The annual direct cost was €1314(SD=736) for injuries within the first year of management, €1318 (SD=817) for injuries in the second and third year and €744 (SD=445) for older injuries.

3.1.7. Indirect costs

Indirect costs were defined as the non-clinical costs incurred by patients following their visit to the hospital and included travel cost, childcare cost and loss of working time (production loss).

The cost of public transport was obtained from the questionnaires. For those who did not indicate the cost in the questionnaire and those who used private transport, the travel cost was calculated by multiplying the distance travelled by the government-approved mileage rate of 47.82 cent /Km. In the study sample, 32/95 (33.6%) patients took public transport only, 49/95(51.6%) used private transport and the remaining 14/95 (14.7%) alternated between the two modes over the study period.

Parents were asked to indicate any incurred childcare costs per hour in the questionnaire. A total cost was calculated by multiplying the hourly cost by the total time spent (appointment time and a travel time). Some parents (22.1%) in the study had to pay for childcare during their attendance at DDUH for their injured child's appointment. The average indicated cost in the questionnaires was €15 per hour.

Production loss was estimated by multiplying the number of missed working hours by the average industrial wage. About two thirds (61.05%) of parents reported missing working hours. The number of missing hours ranged from 1-2 hours to one full day. Production loss was estimated based on the average industrial hourly wage (€21.83) for the year 2016 in Ireland.

Indirect costs per patient were recorded prospectively at each visit for a one-year period. Age and gender did not significantly influence the average annual indirect cost (Table 3.7).

Table 3.7: The mean annual indirect costs (€) as analysed by gender and age groups

Variable	Indirect costs (€)	*P-value
Gender		
Males	389.4 (SD=443.6)	0.49
Females	452.1 (SD=410.5)	
Age		
<11 yr	413.3 (SD=385.3)	0.98
≥11 yr	411.7 (SD=525.3)	
*Simple independent t-test		

The average annual indirect cost was €430 (SD=453) and €350(SD=338) for complicated and uncomplicated injuries respectively showing no statistically significant difference (p-value=0.38).

The average annual indirect cost was €453(SD=422) for injuries within the first year of management, €527 (SD=507) for injuries in the second and third year and €152 (SD=185) for older injuries.

3.1.8. Total costs

The total cost was calculated from the sum of direct and indirect costs for each patient at each visit. The total cost was recorded prospectively at each visit for a one-year period. Age and gender did not significantly influence the average annual total cost (Table 3.8).

Table 3.8: The annual total cost (€) as analysed by gender and age groups

Variable	Average annual total cost (€)	*P-value
Gender		
Males	1601.2	0.88
Females	1634.0	
Age		
< 11 years	1653.7	0.61
≥ 11 years	1521.5	
*Simple independent t-test		

The total cost was €1687.9 (SD=1129.9) and €1350.8 (SD=800.6) for complicated and uncomplicated injuries respectively with no statistically significant difference (p-value=0.13) (Figure 3.8).

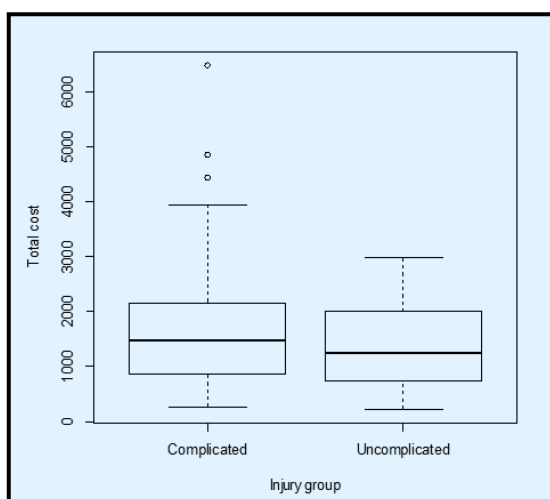


Figure 3.8: The total annual cost for complicated and uncomplicated injuries in the entire sample

However, when new injuries in the first year were analysed separately, significant difference was noted between the two injury groups. The total cost for complicated injuries was €1977.2 (SD=1021.1) and €1000.9 (SD=590.6) for uncomplicated injuries (Figure 3.9).

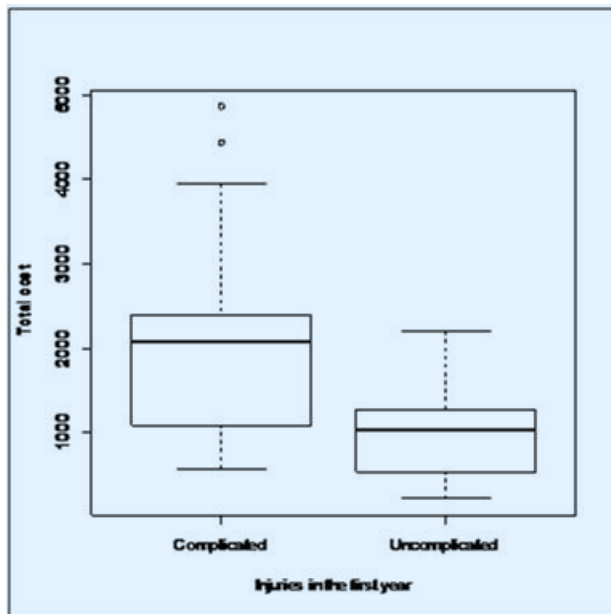


Figure 3.9: The total annual cost for complicated and uncomplicated injuries in the first year

When analysed by injury date for the entire sample, the annual total cost was €1766.7 (SD=1023.5) for injuries in the first year, €1845.8 (SD=1265.7) for injuries in the second or third year of management and €895.9 (SD=512.4) for older injuries (Figure 3.10).

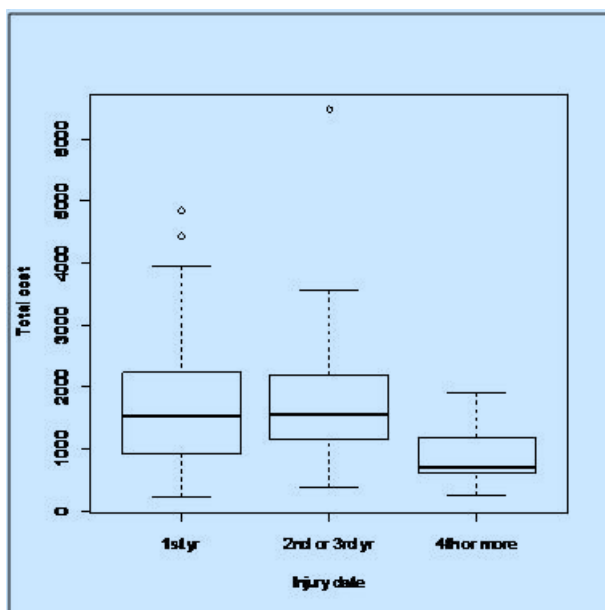


Figure 3.10: The total annual cost for all injuries duration in the entire sample

3.2. The linear regression model

A linear regression model was used to investigate any statistically significant relationship between independent variables and the total cost. As mentioned previously, the data set did not initially fit the linear regression model and assumption of normality was not satisfied, therefore transformation of data by taking the total cost logarithm was undertaken (see statistical analysis in materials and methods). For interpretation, data had to be back-transformed by taking the exponential of the total cost. The results of the linear regression model are displayed in Table 3.9.

Table 3.9: Back-transformed linear regression output

Variable	Estimate	95% CI	P-value
Age (> 11 years)	0.93	0.81-1.06	NS
Gender (females)	0.92	0.81-1.04	NS
Injury group (uncomplicated)	0.90	0.77-1.04	NS
Injury date (2-3 years)	1.22	1.03-1.43	0.02 ***
Injury date (≥4 years)	0.94	0.79-1.12	NS
Distance group 2(25-50 Km)	1.09	0.92-1.28	NS
Distance group 3 (50-75 Km)	1.23	1.01-1.50	0.04 ***
Distance group 4 (75-100 Km)	1.07	0.75-1.52	NS
Distance group 5 (>100 Km)	2.08	1.52-2.86	<0.001 ***
Visit	1.25	1.22-1.28	< 0.001 ***
GA required	0.84	0.67-1.07	NS
*Adjusted R-squared 0.82 (i.e. more than 80% of the variation in total cost is explained by variables in the model) Baseline variables are the variables to which the comparison was made to and are not listed in the above Table. These comprise: age < 11 year, male gender, complicated injury group, injury date within the 1st year, and no hospitalisation.			

3.2.1. Interpretation of the output

The only factors found to have statistically significant influence on the cost were injury date (for injuries in the second or third year of management), distance travelled (for those who travelled 50-70 Km and more than 100 Km), and number of visits. The estimate value presented in Table 3.9 represents the percentage of increase in the total cost compared to the baseline variable.

From Table 3.9, it can be estimated that:

- Total cost for injuries in their 2nd and 3rd year will be 22% higher (95% CI 3.46-43.3%) than injuries in their 1st year.
- Total cost will be 23% higher (95% CI 1.0-50.0%) for distance group 3 (50-75 km) than distance group 1(<25 km)
- Total cost will be about 100% higher (95% CI 52.0- 185.0%) for distance group 5 (>100 km) than distance group 1(<25 km)
- Total cost will increase by 25% for every additional visit

3.2.2. Point predictions

The average total cost for the individuals in the different groups was estimated using R software. The most commonly encountered variables were chosen for estimating point predictions. These are shown in Table 3.10. The point prediction calculates the cost for a subset of patients based on selected mix of characteristics.

Table 3.10 shows cost point prediction for a selection of patient types based on the overall characteristics of the population in the current study. As mentioned previously, 69.5% of the patients were younger than 11 years of age, 77.9% had complicated injuries, and 61.1% travelled less than 25 Km.

From the table, for example, the predicted total cost for males who were less than 11 years of age, with a complicated trauma which was not older than one year, who had to travel less than 25 km, and attended an average number of 6 visits in a year without requiring GA for treatment, was estimated as €1426.4. Other examples are listed in table 3.10.

Table 3.10: Cost point predictions

Age	Gender	Injury group	Injury age	Distance travelled	Number of visits	GA	Predicted cost (€)
< 11 yr	Males	Complicated	≤1 st yr	< 25 km	6	No	1426.4
< 11 yr	Females	Complicated	≤1 st yr	< 25 km	6	No	1552.5
< 11 yr	Males	Complicated	≥4 th yr	< 25 km	4	No	859.2
< 11 yr	Females	Complicated	≥4 th yr	< 25 km	4	No	935.2

CHAPTER FOUR: DISCUSSION

This is the first study in Ireland to report the cost of traumatic injuries to permanent teeth. It is also the first prospective work on this topic since the introduction of the IADT guidelines. The IADT guidelines have given direction to the management of TDI which includes a standardised review visit protocol. The number of visits and type of treatment are among other factors that can affect costs incurred by the individual following an injury. The aim of the study was to estimate the total cost of managing TDI to the permanent dentition in children in Ireland.

The study was completed at the Dublin Dental University Hospital over a one-year period where 104 patients were consecutively enrolled in the study. Nine patients dropped out and was explained by patient request for care continuation at a local service or due to financial reasons. The mean age of the study population was 10.5 years (range of 6-16 years). More than two thirds (69.47%) of the children were younger than 11 years. Therefore, the majority of the injured teeth were immature with incompletely formed roots. Eleven years of age was used as a cut-off point between the two groups as it has been suggested that injuries before this age are likely to need more time and higher costs because of the open apices (Borssén et al., 2002). The male to female ratio was 1.71:1 which is similar to the reported male-to-female ratio of trauma prevalence in children (Glendor, 2008; Lam, 2016). This demonstrates that the sample was representative from a gender point of view.

However, from an injury type point of view, the sample of the current population was biased. The majority (77.9%) of the sample had a complicated injury. The DDUH is considered a referral centre and most of the complex injuries are seen in the specialised Trauma Clinic. It is very likely that a typical dental practice would have a larger proportion of uncomplicated injuries. Although an attempt was made to recruit simple uncomplicated injuries for the study, poor enrollment of children with these injuries remained an issue throughout the study period. Individuals with simple injuries are less likely to attend A&E service for treatment, and if they do, it is the hospital policy to refer these patients to a local primary care centres for follow up unless they agreed to participate in a clinical research. Collectively, these factors resulted in the greater enrollment of complicated injuries compared to uncomplicated ones. That said, it is noteworthy to mention that the operating

practice in the paediatric dental unit had changed over the course of the study. In previous years, patients with uncomplicated injuries were referred back to primary care centres for treatment and follow up, however, for the purpose of this study, and in order to ensure that the maximum number of uncomplicated injuries was enrolled, patients with this type of injuries were reviewed by the investigator in the paediatric unit at the hospital. The potential impact of this change could be that the type of injuries retained in the hospital over the study period is different from those retained in past years.

Injuries were also subdivided by the various types according to Andreasen's classification (Andreasen et al. 2013) (Table 3.2). Avulsion was the most prevalent injury (26.3%) and uncomplicated crown fracture were the second most prevalent (22.1%) in the current study population. This finding reflects the biased population with the more complex injuries in Trauma Clinic at DDUH. Crown fracture is the most common injury reported in the literature in the permanent dentition (Schuch et al., 2013, Damé-Teixeira et al., 2013b, Altun et al., 2009, Dua and Sharma, 2012). Categorization of injuries by the various subtypes resulted in too few numbers for statistical analysis at this level; therefore analysis was restricted to the two main groups of injuries; uncomplicated and complicated.

The average number of visits in one year was 5.4 visits regardless of the injury group. This is the first study to report no significant difference in the average number of visits for complicated and uncomplicated injuries, unlike previous reports which found that complicated injuries required significantly higher number of visits (Glendor et al. 1998; Glendor et al. 2000a). In the current study, it was found that a number of 5.6 and 4.9 visits was required for complicated and uncomplicated injuries respectively with no significant difference between the two groups. This unexpected finding can be explained by the fact that this estimation was based on the entire sample with a mix of injuries that were at various stages of treatment and observation periods. Many injuries in the uncomplicated category in the current population developed some complications after their first year which increased the number of visits in this category and subsequently led to insignificant difference between the two groups. Interestingly, it was noted that uncomplicated injuries in the current population were developing complications at a higher rate (33%) compared to what is reported in the literature (1-16%) (Andreasen et al. 2013). This can be mostly explained by inaccurate or missed

diagnosis in the current sample particularly missing a concurrent luxation injury such as concussion or subluxation.

Separate analysis for injuries in the first year (Figure 3.6), revealed a statistically significance increase in the number of visits following complicated injuries (6.6 visits) compared to uncomplicated injuries (4.3 visits) during the first year. The recall visits were proposed to patients according to the IADT review protocol. The numbers reported in this study generally reflects a high level of adherence to the IADT recommendations at the Trauma Clinic. However, it is worth mentioning that TDI are unpredictable in nature and there is always unforeseeable likelihood of complications.

In the literature, two studies reported an increase in the number of visits required for TDI in the first year. Glendor et al.1988 also reported a per-individual number of visits over the first year after trauma. The study found that 11.9 visits were required for complicated injuries compared to 6.2 visits for uncomplicated injuries. These figures are higher than the findings in the present study. The difference may be explained by the fact that Glendor's study was carried out before the development of the IADT guidelines whereas in the current investigation, all injuries were prospectively followed up according to the IADT review protocol. Nguyen et al. 2004 also estimated the number of visits required in the first year but limited his investigation to avulsed incisors only. The authors reported an average number of (9.1) visits needed during the first year. Similar data were extracted from our study sample and analysed separately. The average number of visits was found to be 5.9 visits for avulsed incisors in the present sample during the first year. This difference can be explained by adherence to the IADT review protocol in the current study. It can be proposed that the implementation of the IADT management guidance has reduced the unnecessary recalls for complicated injuries. Nevertheless, as a limitation in the current work, no objective measure was taken to assess that operators were actually following the guidelines and an audit would have been useful.

The highest number of visits occurred within the first year following the injury in agreement with previous studies (Glendor 1998; Nguyen et al. 2004) and the IADT guidelines. This finding reflects the increased monitoring required in the first year until stabilisation of the pulpal and periodontal status.

The number of visits was not influenced by gender. There was no significant difference in the number of visits between the two age groups in the study. This contradicts a previous study by Borssén et al. 2002 who reported longer treatment time when injuries occurred before the age of 11 and attributed that to the immature roots and the need for apexification. In the present study, the majority of our population older than 11 years had complicated injuries that needed frequent visits therefore masking any potential difference due to the age. Another explanation could be the adherence to the IADT review protocol in the Trauma Clinic at the DDUH.

The study sought to estimate direct costs and indirect cost as defined in Table 2.3 and attempted to capture all costs regardless of the payer. In the present sample, 21/95 (22.1%) had a medical card and were entitled for free treatment, 42/95 (44.2%) were covered by accidents insurance or other forms of dental insurance, and 32 (33.6%) paid directly for their child's treatment.

The total cost (both direct and indirect) was investigated in relation to independent variables (injury group, injury date, gender and age). Interestingly, total cost did not differ significantly between complicated and uncomplicated injuries except for new injuries in the first year. Complicated injuries were almost as twice as expensive (€1977) in the first year compared to uncomplicated injuries (€1000). This could be mostly explained by the significant increase in the number of visits between complicated and uncomplicated injuries during the first year and also by the treatment needs. Among the population with the new complicated injuries, 20/40 (50%) required root canal treatment, 2/40(5%) required active orthodontic traction, 3/40 (7.5%) required extraction with a provision of interim partial denture and 3/40 (7.5%) required GA for management of their injury during the first year (Appendix K). These treatment needs are clearly more expensive than monitoring or restorative visits required for patients with the uncomplicated injuries in the first year following injury.

However, when total cost was analysed for the entire sample, the estimated values were comparable for complicated and uncomplicated injuries. The most likely explanation is the unpredictable nature of TDI. Teeth with uncomplicated injuries remain at risk of developing complications. In the current study, one-third (7/21) of the uncomplicated injuries developed endodontic complications and

subsequently required more intervention comparable to the complicated injuries. Another explanation might be the small numbers in the uncomplicated group that did not allow detection of statistical significance.

When analysed by the injury date, the total cost did not reduce despite the decrease in the number of visits. The cost was higher for injuries in their second and third year of management than in the first year. In the current sample, active orthodontic treatment with fixed appliance was required by one patient with an injury in the second group (injuries in the 2nd-3rd year) (Figure 3.10) following a severe intrusion. The additional charge (€1245) of the fixed appliance resulted in the higher cost. Figure 3.9 also shows two outliers in the first year; these patients required either GA or removable orthodontic appliance, both less expensive than fixed orthodontics. Throughout the study, patients with most expensive treatment had required GA or orthodontic treatment. The study did not exclude any trauma-related costs; therefore this inclusion will give a truer estimation of trauma-related costs. It is postulated that a study with a larger sample size could detect more of these cases that need additional expensive procedures.

Injuries older than 4 years resulted in lower annual total costs. In the current sample, most of the traumatised teeth at this stage of management had been stabilised and placed on annual reviews. Nonetheless, the difference in the cost was not statistically significant when compared to injuries in the first year and this may be attributed to the small numbers in this group.

Gender had no statistically significant influence on costs. This finding was also reported by Glendor et al. 2001. In the literature, there is no report of gender-related healing complications, therefore management and subsequent costs should be the same. Although a study by Andreasen et al. 2004 reported better healing outcomes in root-fractured incisors in girls, the difference was due to injuries sustained at younger age in girls rather than actual gender influence and the difference was not significant when gender was analysed against the various groups of root development.

In the present study, age-related difference in the cost was not evident. In contrast, Glendor et al. suggested likely increased costs in "pre-teen" children due to immature roots and higher risk of sustaining multiple injuries if the first trauma episode occurred before the age of 11 (Andreasen et al., 2013). In the current

study, although younger patients required apexification and exhibited more behavioural difficulties in the clinical settings, the majority of the older children had complicated injuries that required advanced and multidisciplinary management. Even after controlling for the injury date, analysis of data of injuries in the first year revealed no statistically significant difference between the two age groups.

The distance travelled also influenced the cost. As one would expect, as the travel distance increases, the travel cost will increase. However, this association was lacking in group 2 (25-50Km) and group 4 (75-100 Km) and this may be due to the small sample in these groups. The majority of our patients lived within 25 Km from the hospital. This suggests that access to expertise at a local facility would help contain costs.

The use of GA increased treatment cost significantly (€1771.0) compared to cases managed solely in the Trauma Clinic (€406.1); nevertheless the linear regression model did not confirm a statistically significant difference which is possibly explained by the small number; only 3 patients required GA over the study period. This reflects that the majority of traumatised teeth can be managed without the need for the increased expenses of GA or additional adjunct services.

In the current work, we estimated that the average cost of dental treatment was €449.1 per tooth per patient in one year. Based on the number of children (aged 6-16 years) in Ireland and an annual incidence rate of TDI of 1% in the permanent dentition in school children, the approximate cost of treating TDI can be estimated as €4 million per million individuals. This compares to a previous study by Borum and Andreasen in Denmark whereby an annual treatment cost of traumatic injuries was estimated by dividing the yearly cost of running the trauma centre by the number of injured teeth treated in one year. The authors reported an annual cost of \$2-5 million per million individuals irrespective of age (Borum and Andreasen, 2001). This represents a significant burden to any healthcare system.

As previously mentioned, Nguyen et al. estimated an average treatment cost (including cost of radiographs) for avulsed permanent incisors. The authors reported a cost of \$1465 CAD in the first year following replantation. Separate descriptive analysis for the avulsed teeth in the first year (n=10) in the present study revealed an average treatment cost (including cost of radiographs) of €533. Obviously, we are reporting a significantly lower annual cost for the same category

of injuries over the same period but for only ten teeth. This could be explained by the fact that Nguyen's retrospective analysis included avulsed teeth that were replanted in the period of 1988-1999 with a mean extra-alveolar time of 93 min. The standard of care for avulsed teeth was more variable before the introduction of the IADT guidelines on the acute management of avulsed teeth. However, statistical analysis on costs by the various injury types was not possible due to the small numbers in each category.

The literature on dental trauma cost is scarce and no data is available in Ireland. The costs presented in this work are not readily comparable to previous reports in the literature due to marked variation in the methodology, particularly in relation to costs definition and valuation. The data in this study are more detailed due to the prospective nature of data collection. Furthermore, the published studies are at least ten years old and in view of the yearly prices inflation, comparison is less meaningful if valid at all.

As in all costing studies, accurate determination of all incurred costs is almost not possible, however rough estimation can still be insightful. In the current study, certain elements of under- or over-estimations in costing methodology could be identified. Indirect costs were calculated from information sought in the self-completed questionnaires. Estimation of travel cost was assigned for those who did not indicate the actual cost and could have led to some over-estimation. For working parents, production loss was estimated based on the average industrial wage but parents were not asked to indicate their occupation or their income. This could represent over- or under-estimation of costs as we did not account for the degree for employment (part-time vs. full-time) or the actual hourly earnings. The study did not report missed school time or lost educational opportunities.

The presence of different operators with different training levels in Trauma Clinic may result in different costing which possibly influenced the cost in the various groups. It is worth mentioning that operator variation did not affect the management of TDI as all operators used the IADT guidelines for clinical management and follow up. In addition, the cost of the treatment provided varied from visit to visit. However, as the primary question of the current investigation was to look at the total cost of TDI in one year, these factors were not included in the final analysis due to visit-to-visit variation over the one-year period. However,

accounting for operator level and type of treatment should be considered for future research for more specific clinical costing.

The selection of the most severely injured tooth for cost analysis might have led to higher estimation. However, complicated dental injuries are relatively frequent especially in referral centres like the DDUH and an insight of the average cost in this category of patients is still valuable and essential-to-know for policymakers and health institutions for efficient allocation of resources.

On the other hand, these costs might be underestimated as they were calculated only for one tooth in one patient. Future research could investigate the cost of multiple injuries per patient per year. Furthermore, the current study also estimated costs for one year only, which does not represent the real outcome of such complex injuries where patients are often committed to a lifetime dental treatment. It is also worth mentioning that the DDUH price list which was used in the current investigation is less compared to what is being charged in private dental practice.

True health economic evaluation was not considered and this could have underestimated the total cost by not including costs such as loss of property and loss of leisure time. However, the current study aimed to get an estimation of the most commonly incurred direct and indirect costs. The approach adopted in this study could be reproduced and would be interesting to see comparable data from other countries.

4.1. Conclusion and direction for future research

Management of TDI is costly and time-consuming in this group of patients requiring frequent visits and speciality expertise. This study showed that complicated injuries in the first year are the most expensive and these were twice as costly as uncomplicated injuries during the first year.

Implementation of IADT guidelines may help reduce the cost by standardising the number of visits. The study estimated that the total cost increased 25% with every additional visit.

The cost indicated in this study could be useful in allocation of resources for a trauma service. Implementation of a robust trauma prevention programmes would result in cost savings. It is anticipated that results of this work will be useful for informing Irish healthcare providers and policymakers in the effective use of limited resources.

Further research in this area is encouraged to add to the rather scarce literature. Larger prospective population-based studies in collaboration with health economists may give a more accurate insight about the economic burden of these injuries.

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Online resources:

1. <https://www.iadt-dentaltrauma.org/> (last accessed July 2017)
2. <https://dentaltraumaguide.org/> (last accessed July 2017)
3. <https://www.dcy.gov.ie/documents/stateofthenationschildren/20170302SOTNCRReport2016> (last accessed July 2017)
4. <https://maps.google.ie/> (last accessed June 2017)
5. www.revenue.ie (last accessed June 2017)
6. http://www.hse.ie/eng/staff/benefitservices/Travel_Subistence/Travel_Subistence_Rates (last accessed February 2017)
7. <http://www.cso.ie/en/statistics/earnings> (last accessed February 2017)
8. www.rcommander.com (last accessed July 2017)
9. <https://www.rcran-project.org/> (last accessed July 2017)

APPENDICES

Appendix A: Andreasen's classification of TDI

Injuries to teeth:

- Crown infarction
Incomplete fracture (crack) of the enamel without loss of tooth substance
- Uncomplicated crown fracture
A fracture with loss of enamel or dentin without exposing the pulp
- Complicated crown fracture
A fracture with loss of enamel or dentin and exposing the pulp
- Crown-root fracture
A fracture involving enamel, dentin and cementum
- Root fracture
A fracture involving dentin , cementum and pulp

Injuries to periodontal tissues

- Concussion
Injury to tooth supporting tissues without loosening or displacement of the tooth
- Subluxation
Injury to tooth supporting tissues with abnormal loosening but without displacement of the tooth
- Intrusive luxation
Displacement of the tooth into the alveolar bone often accompanied by comminution or fracture of alveolar socket.
- Lateral luxation
Displacement of the tooth in a direction other than axially often accompanied by comminution or fracture of alveolar socket
- Extrusive luxation
Partial displacement of the tooth out of its socket
- Avulsion
Complete displacement of the tooth out of its socket
- Alveolar bone fracture
Fracture of tooth-supporting bone may or may not involve the alveolar socket

Appendix B: Letter of ethical approval



DUBLIN DENTAL UNIVERSITY HOSPITAL

TRINITY COLLEGE DUBLIN SCHOOL OF DENTAL SCIENCE

Division of Oral Biosciences
School of Dental Science
Dublin Dental School & Hospital
University of Dublin, Trinity College
Lincoln Place, Dublin 2, Ireland

Dr Thikrayat Bani-Hani,
Dublin Dental University Hospital
Lincoln Place, Dublin 2, Ireland

03/07/2017

Dear Thikrayat,

RE: The cost of treating injuries to adult teeth in children

Thank you for your application to the School of Dental Science Research Ethics Committee in July 2015 for approval to carry out the above-named study.

This letter is to confirm that the committee reviewed your application in July 2015. Following the implementation of some minor amendments, the committee were satisfied with this application and granted ethical approval for the study to commence.

Yours sincerely,

Gary Moran
Chair of DDUH Research Ethics Committee
Director of Research
Associate Prof. in Microbiology

Division of Oral Biosciences, Dublin Dental School and Hospital, Trinity College Dublin, Lincoln Place, Dublin 2, Ireland
Phone: +353 1 6127245 Fax: +353 1 6127295
Email: gpmoran@dental.tcd.ie Website: <http://people.tcd.ie/gmoran>

Appendix C: Sample size calculation

Table 1: Sample Size Estimation for Multiple Linear regression

Alpha	Power	Effect Size	Total Sample size*
0.05	0.8	0.02	688
0.05	0.8	0.15	98
0.05	0.9	0.02	878
0.05	0.9	0.15	122
0.01	0.8	0.02	953
0.01	0.8	0.15	135
0.01	0.9	0.02	1168
0.01	0.9	0.15	164

* Figures should be increased by 10% to allow for drop-outs/loss to follow-up

- Alpha denotes the probability of a Type 1 error
- Power denotes 1-the probability of a Type 2 error
- A Type 1 error is the probability of finding an effect that is not there (i.e. rejecting the null when it is true)
- A Type 2 error is probability of finding no effect when there is an effect (i.e. fail to reject the null when it is false)
- Based on Cohen - effect size of 0.02 is regarded as small and 0.15 is regarded as medium effect size. These effect sizes are guidelines and clinical judgment/knowledge of your patient population can be used to revise these effect sizes.

Table2: Sample Size Estimation for t-test

Alpha	Power	Effect Size	Sample size for EACHgroup
0.05	0.8	0.20	394
0.05	0.8	0.50	64
0.05	0.9	0.20	526
0.05	0.9	0.50	85
0.01	0.8	0.20	586
0.01	0.8	0.50	95
0.01	0.9	0.20	746
0.01	0.9	0.50	121

- Alpha denotes the probability of a Type 1 error
- Power denotes 1-the probability of a Type 2 error
- A Type 1 error is the probability of finding an effect that is not there (i.e. rejecting the null when it is true)
- A Type 2 error is probability of finding no effect when there is an effect (i.e. fail to reject the null when it is false)
- Based on Cohen - effect size of 0.2 is regarded as small and 0.5 is regarded as medium effect size. These effect sizes are guidelines and clinical judgment/knowledge of your patient population can be used to revise these effect sizes.

Appendix D: Invitation letter

Invitation letter

Dear Parent/Guardian ,

This is Dr.Thikrayat Bani-Hani, a postgraduate student in paediatric dentistry at the Dublin Dental University Hospital (DDUH). I am carrying out a research to estimate the cost and time spent in treatment of injured teeth in children.

If you are willing to have your child enrolled in my study, I would like you to give me permission to access the following data in your child's records:

Age, gender, place of residence, type and date of the dental injury, ,
type and cost of treatment provided , number of visits attended for the injury.

If you are happy to participate in this study, you will be asked to sign a consent form on the day of your child's appointment and fill in a 10-item questionnaire about any incurred cost related to your visit.

More information can be found in the enclosed information leaflet.

Kind regards,

Dr.Thikrayat Bani-Hani

Postgraduate student in Paediatric Dentistry ,

Dublin Dental University Hospital

Lincoln Place

Dublin 2,

Patient Information Leaflet

The cost of treating injuries to teeth in children

Introduction:

Dental trauma is common; about one quarter of Irish children have suffered trauma to their teeth. Management of these injuries is costly and time-consuming.

The purpose of this project is to estimate the total cost and time spent in treatment of injured adult teeth in a child.

The following data will be collected from your child's clinical records:

Age, gender, place of residence, type and date of the injury, number of teeth injured, treatment cost , number of visits attended for the injury, and child's behavior.

In addition we will be asking you to fill in a questionnaire at each visit.

Your child may be included in the study if s/he fulfills the following criteria:

- Dental trauma to at least one tooth
- Age 6-16 years
- Existing patient who has been regularly attending for their appointments
- New patient to be followed-up at Dublin Dental University Hospital (DDUH)

Patient Information Leaflet



Your child may NOT be included in this study if any of the following are true:

- Your child is unable to cope with dental treatment: these children often require more clinical time and increased number of visits to finish planned treatment and may be excluded from the study.
- Your child fails to attend two or more visits without an obvious reason
- If the injury history or documentation in your child's records is incomplete

All parents/companions of children who meet the inclusion criteria will be invited to participate in the study.

Consenting participants will be given a short questionnaire to complete at each visit over a period of one year.

There are **no potential risks or anticipated direct benefits** to the individual participants. However we hope that the study will give parents as well as health care professionals an estimate about the economic burden being spent on treating these injuries so that more effective management can be implemented. This study is also important to inform healthcare policy makers to ensure effective use of the limited resources.

Compensation:

- There is no payment associated with this study.
- Nothing in this document restricts or curtails your rights.
- Your dentists are covered by standard medical protection insurance.

Patient Information Leaflet



Voluntary Participation and withdrawal:

You have volunteered to participate in this study. You may quit at any time. If you - or your child- decide not to participate, or if you quit, you will not be penalised and will not give up any benefits which you had before entering the study.

You do not have to be a part of this study to be treated at DDUH. If you decline to participate we will still carry out treatment of your child. It will NOT affect your right to treatment.

Confidentiality:

Your identity will remain confidential. Your name will not be published and will not be disclosed to anyone outside the study group.

Your child will be identified in all records/data by his/her hospital number. Access to your child's records and data from this study will be limited to dentists in the research group. Any computerized information will be stored on password-protected computers with restricted access. The study data will be kept for 5 years after the study is completed in a locked cabinet but will NOT be used for any future unrelated studies without your permission.

Stopping the study:

You understand that your participation in the study can be stopped by the treating dentist at any time without your consent. This will have no impact on your child care.

Permission:

The study has been approved by the School of Dental Science Research Ethics Committee, Trinity College Dublin

Patient Information Leaflet



Access to data:

The data collected regarding your child will be available for you to see at any point during the study by asking a team member.

Use of data:

The results from this study will be presented as part of a thesis in the primary researcher's Doctorate degree. It is also hoped that the finding will be published in a suitable dental journal or in lecture format so that others can benefit from the information.

Further information:

You can get more information or answers to your questions about the study, your participation in the study, and your rights, from

DrThikrayatBani-Hani, Postgraduate in Pediatric Dentistry ,Dublin Dental Hospital, Lincoln Place, Dublin 2

Dr. Anne O'Connell, Associate Professor/Consultant, Department of Public and Child Health, Dublin Dental Hospital, Lincoln Place, Dublin 2

Or from an independent gatekeeper; *Louise Henshaw* at phone 016127303

Appendix F: Consent form

Consent Form

Title of research study:

The cost of treating dental injuries in children

This study and this consent form have been explained to me.

I have read, or had read to me, this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to me and my child's legal and ethical rights. I have received a copy of this agreement.

I give permission for the data from my child's dental records to be included in the overall findings of this research, which will be published in relevant dental literature.

I understand that I may withdraw from the study at any time and that will NOT affect or interrupt with the treatment that my child is receiving.

CHILD'S NAME:

PARENT'S / ACCOMPANYING PERSON'S NAME:

PARENT'S / ACCOMPANYING PERSON'S SIGNATURE:

Date:

Statement of investigator's responsibility: I have explained the nature, purpose, procedures, benefits, risks of, or alternatives to, this research study. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Signature of person taking the consent:

Date:

Appendix G: Assent form

Assent Form

Title of research study:

The cost of treating dental injuries in children

This study and this consent form have been explained to me.

I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely agree to be part of this research study. I have received a copy of this agreement.

I give permission for the data from my dental records to be included in the overall findings of this research, which will be published in relevant dental literature.

I understand that I may withdraw from the study at any time and that will NOT affect or interrupt the treatment that I am receiving.

CHILD'S NAME:

CHILD'S SIGNATURE:

Date:

Statement of investigator's responsibility: I have explained the nature, purpose, procedures, benefits, risks of, or alternatives to, this research study. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Signature of person taking the consent:

Date:

Appendix H: Questionnaire

ID								
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Date -----

Overall cost of your dental visit

1. **How did you get to the hospital today?** (please indicate the way you travel for the main or the longest part of your journey):

- ☐ Taxi
- ☐ Private car
- ☐ Train
- ☐ Bus
- ☐ Cycling
- ☐ Walking
- ☐ Other (please specify)

- **Please estimate the cost of your return journey for your family to travel here today (please include taxi/bus fare, parking fees, petrol cost or any other relevant cost in euro €.....)**

2. **How long did it take you to get to the hospital?**

- ☐ Less than one hour
- ☐ 1-2 hours
- ☐ More than 2 hours

3. **How long was your dental appointment today (including the waiting time)?**

- ☐ Less than 30 min
- ☐ 30-60 min
- ☐ 60-90 min
- ☐ More than 90 min

4. **Who pays for your child's treatment:**

- ☐ Self-pay
- ☐ Medical card
- ☐ School accident insurance
- ☐ Other (please specify)

5. **Did you get someone to look after other child/children or other dependents at home while accompanying your child today?**

- ☐ Yes
- ☐ No
- ☐ Not applicable

- **If yes, please answer the following:**

- **Do you pay that person?**

- ☐ Yes
- ☐ No

- **If yes, please indicate how much it will cost? (cost in euro) €.....**

ID							
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6. Did you have to take any time off from paid work (or business activity if self-employed) to accompany your child to his/her dental appointment today?

- ☐ Yes
☐ No

- If yes, approximately how much time did you take off from work?

- ☐ Less than an hour
☐ 1-2 hours
☐ 2-3 hours
☐ More than 3 hours

7. Since your last visit, has your child ever needed to take any medications for the dental injury?

- ☐ Yes
☐ No

- If yes, please give the approximate (cost in euro): €.....

8. Since your last visit, have you spent any money on a sportguard or denture repair for your child following his/her dental injury?

- ☐ Yes
☐ No

- If yes, please give the approximate (cost in euro): €.....

9. Since your last visit, have you visited another health care professional regarding the dental injury of your child?

- ☐ Yes
☐ No

- If yes, please indicate how much did you have to pay? (cost in euro) €.....

10. Do you think you have incurred any other costs not mentioned here following your child's dental injury?

- ☐ Yes
☐ No

- If yes, please specify,

Thank you for your time



Appendix I : Data extraction sheet

Data extracted from patients record

Hospital number
Gender
Date of birth
Address
Injury diagnosis(es)
Date of injury
Date of first visit
Hospitalization /admission due to injury
Number of x-ray
Operator (level of training)
Type of treatment provided

Appendix J: Statistical analysis - Linear Regression Model

```
#linear regression model
>model<-lm(Total.cost~age+sex+InjGrp+DistGrp+ageInj+visit+GA)
>summary(model)

Call:
lm(formula = Total.cost ~ age + sex + InjGrp + DistGrp + ageInj +
    visit + GA)

Residuals:
    Min       1Q   Median       3Q      Max
-1126.78  -266.77    -9.74   236.91  1228.41

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  -343.674    152.709  -2.251  0.02706 *
age[T.2]      -114.774     101.173  -1.134  0.25988
sex[T.2]      -152.597      98.300  -1.552  0.12438
InjGrp[T.2]    -76.593     113.925  -0.672  0.50326
DistGrp[T.2]   -60.898     124.698  -0.488  0.62658
DistGrp[T.3]   459.615     148.672   3.091  0.00271 **
DistGrp[T.4]   247.392     265.628   0.931  0.35438
DistGrp[T.5]  1036.857     235.864   4.396 3.24e-05 ***
ageInj[T.2]    170.639      122.027   1.398  0.16573
ageInj[T.3]      3.134       132.097   0.024  0.98113
visit         343.703       20.063  17.131 < 2e-16 ***
GA[T.2]        414.446       177.649   2.333  0.02207 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 439.9 on 83 degrees of freedom
(9 observations deleted due to missingness)
Multiple R-squared:  0.8511,    Adjusted R-squared:  0.8314
F-statistic: 43.14 on 11 and 83 DF,  p-value: < 2.2e-16

#checking model assumptions:

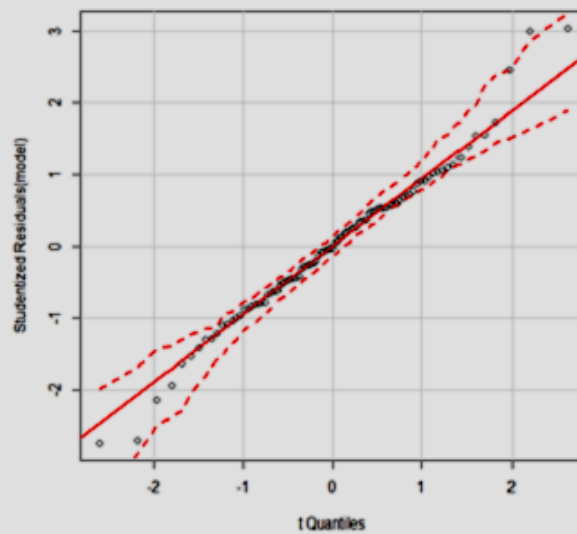
#test for normality
>shapiro.test(model$resid)

        Shapiro-Wilk normality test

data:  model$resid
W = 0.98907, p-value = 0.6263

Shapiro-wilk test for normality shows that assumption of normality
is satisfied (p-value=0.6)
Null hypothesis data is normally distributed
```

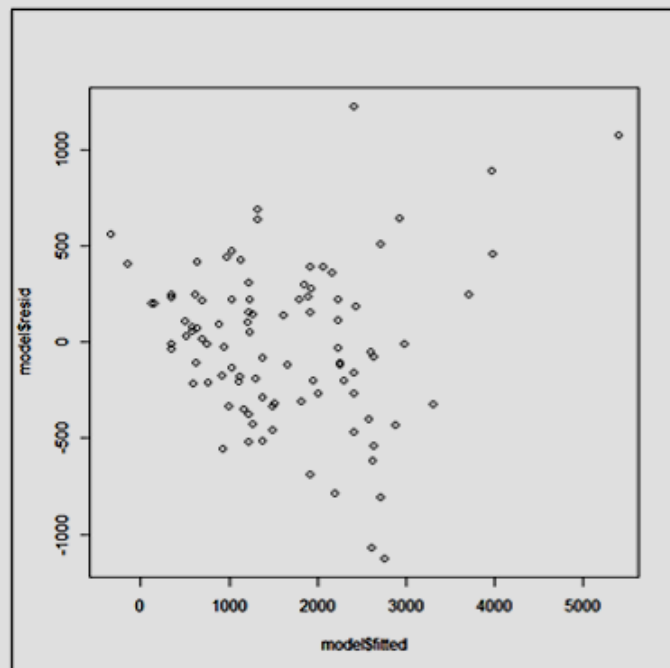
```
#qqPlot  
>qqPlot(model)
```



qqPlot shows assumption of normality is satisfied

```
# test for constant variance  
>library(car)  
>ncvTest(model)  
Non-constant Variance Score Test  
Variance formula: ~ fitted.values  
Chisquare = 25.53178    Df = 1    p = 4.351557e-07  
  
The assumption of constant variance is not satisfied (p-value <  
0.001)
```

```
#plot residual vs.fitted values  
>plot(model$fitted,model$resid)
```



Plot of residuals vs. fitted values shows that the assumption of constant variance is violated (not satisfied) -plot shows a funnel pattern

Transformed data

```
#linear regression model 2
> model2<-lm(logTotal.cost~age+sex+InjGrp+DistGrp+ageInj+visit+GA)
>summary(model2)
```

Call:
lm(formula = logTotal.cost ~ age + sex + InjGrp + DistGrp + ageInj + visit + GA)

Residuals:

	Min	1Q	Median	3Q	Max
	-0.56370	-0.19977	0.01358	0.22333	0.65113

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	5.92074	0.10262	57.698	< 2e-16 ***
age[T.2]	-0.07313	0.06799	-1.076	0.2852
sex[T.2]	-0.08472	0.06605	-1.283	0.2032
InjGrp[T.2]	-0.10984	0.07655	-1.435	0.1551
DistGrp[T.2]	0.08281	0.08379	0.988	0.3259
DistGrp[T.3]	0.20861	0.09990	2.088	0.0399 *
DistGrp[T.4]	0.06426	0.17850	0.360	0.7197
DistGrp[T.5]	0.73404	0.15849	4.631	1.33e-05 ***
ageInj[T.2]	0.19711	0.08200	2.404	0.0185 *
ageInj[T.3]	-0.05945	0.08877	-0.670	0.5048
visit	0.22369	0.01348	16.592	< 2e-16 ***
GA[T.2]	-0.16939	0.11938	-1.419	0.1597

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2956 on 83 degrees of freedom
(9 observations deleted due to missingness)
Multiple R-squared: 0.8397, Adjusted R-squared: 0.8185
F-statistic: 39.53 on 11 and 83 DF, p-value: < 2.2e-16

81.9% of the variation in total cost is explained by variables in the model ,

Note:
For interpretation, this output need to be transformed back to the original format (because it is log transformed data).This will be done by taking the exponential of each value.
Before transforming, model assumptions have to be checked.

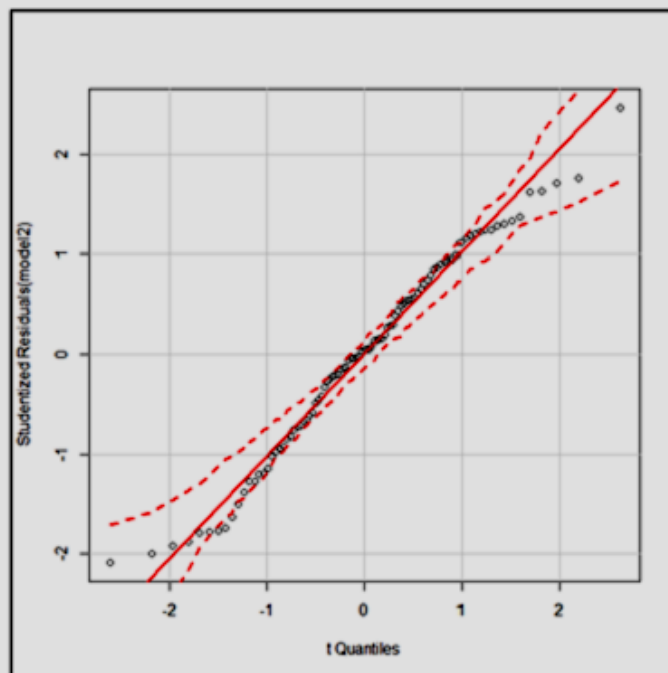
```
#test for normality  
>shapiro.test(model2$resid)
```

Shapiro-Wilk normality test

```
data: model2$resid  
W = 0.9834, p-value = 0.2731
```

Shapiro-wilk test for normality showed that assumption of normality is satisfied (p-value=0.3)
Null hypothesis data is normally distributed

```
#qqplot  
>qqPlot(model2)
```



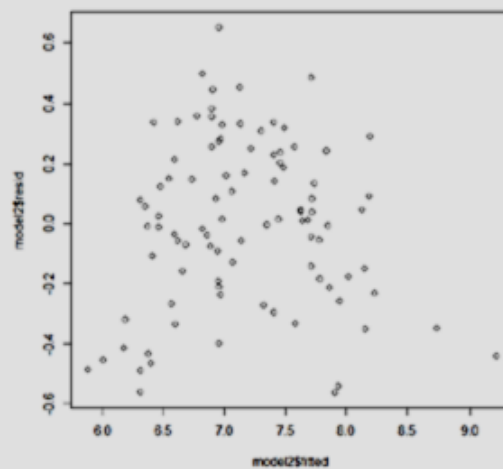
qqPlot showed assumption of normality is satisfied

```
# test for constant variance
>library(car)
>ncvTest(model2)

Non-constant Variance Score Test
Variance formula: ~ fitted.values
Chisquare = 0.7513565    Df = 1    p = 0.3860471

The assumption of constant variance (homogeneity) is satisfied (p-
value = 0.4)
```

```
#plot residual vs. fitted values
>plot(model2$fitted,model2$resid)
```



Plot of residuals vs. fitted values shows that the assumption of constant variance is satisfied) -plot shows no particular **pattern**

```
# Data back transformation for interpretation
>estimate<-exp(model2$coef)
>b<-exp(confint(model2))
>cbind(estimate,b)
```

estimate	2.5 %	97.5 %	P-value	
(Intercept)	372.6890291	303.8834905	457.073572	<0.001***
age[T.2]	0.9294785	0.8119207	1.064058	NS
sex[T.2]	0.9187719	0.8056565	1.047769	NS
InjGrp[T.2]	0.8959801	0.7694331	1.043340	NS
DistGrp[T.2]	1.0863362	0.9195679	1.283349	NS
DistGrp[T.3]	1.2319660	1.0099564	1.502778	0.04***
DistGrp[T.4]	1.0663741	0.7476983	1.520872	NS
DistGrp[T.5]	2.0834857	1.5201402	2.855600	<0.001***
ageInj[T.2]	1.2178785	1.0346032	1.433620	0.02***
ageInj[T.3]	0.9422786	0.7897766	1.124228	NS
visit	1.2506776	1.2175867	1.284668	<0.001***
GA[T.2]	0.8441813	0.6657635	1.070413	NS

Appendix K: Additional analyses used for discussion

For the sake of comparison with the previously published work on this topic, similar data were extracted from the data sheet in the current study and additional analyses were undertaken. These are illustrated in the following section:

- **Year 1 data subset:**
- Nguyen et al. 2004 investigated the treatment cost (not total cost) and the number of visits required following replantation of avulsed teeth in the first year. In the current sample the number of avulsed teeth during the first year was 10, the average treatment cost was calculated to be € 553 and average number of visits was 5.9.
- The treatment needs for the two injury groups were investigated to explain the significant difference in costs. The results are shown in the table below:

Complicated group	Uncomplicated group
20/40 (50%) required root canal treatment/apexification 2/40(5%) required active orthodontic traction 3/40 (7.5%) required extraction with a provision of interim partial denture 3/40 (7.5%) required GA	11/11 (100%) had composite restoration and subsequent reviews

- **Calculation of treatment cost per million individuals:**
- Borum and Andreasen 2001 estimated an approximate annual treatment cost of \$2-5 million per million individuals for TDI in the permanent dentition. In the present study, the average annual treatment cost (not total cost) was estimated to be €449.1 per patient.

Based on data from recent census in Ireland in 2016, the number of children aged 6-16 years was 729,939

Assuming an incidence rate of 1% (the lowest rate in this age group) (Oldin et al. 2015)

The number of children that are likely to present with TDI each year in Ireland

= 729,939 X 1%

= 7,299 children

Treatment cost per 1 child →€ 449.1

Treatment cost for 7,299 children →?

Estimated annual treatment cost for children with TDI in Ireland = 3,277,251

Estimated annual treatment cost per million child = (3,277,251 X 1 mil)/729,939

= € 4,489,760

≈€ 4 million per 1 million

Appendix L: Review protocol for TDI in the permanent teeth as proposed by the IADT

Injury type	Follow-up
Enamel infraction	No follow-up is generally needed unless associated with other injuries.
Enamel fracture	6-8 weeks 1 year
Enamel-dentin fracture	6-8 weeks 1 year
Enamel-dentin-pulp fracture	6-8 weeks 1 year
Crown-root fracture	6-8 weeks 1 year
Root fracture	4 Weeks 6-8 Weeks 4 Months 6 Months 1 Year 5 Years
Concussion	4 Weeks 6-8 Weeks 1 Year
Subluxation	2 Weeks 4 Weeks 6-8 Weeks 6 Months 1 Year
Extrusive luxation	2 Weeks 4 Weeks 6-8 Weeks 6 Months 1 Year Yearly 5 years
Lateral luxation	2 Weeks 4 Weeks 6-8 Weeks 6 Months 1 Year Yearly 5 years
Intrusive luxation	2 Weeks 4 Weeks 6-8 Weeks 6 Months 1 Year Yearly 5 years
Avulsion	4 Weeks 3 Months 6 Months 1 Year Yearly thereafter