Aus der Poliklinik für Zahnerhaltung und Parodontologie

Klinik der Universität München

Direktor: Prof. Dr. Reinhard Hickel

Retrospektive Auswertung unfallbedingter Zahnhartsubstanzverletzungen

Dissertation

Zum Erwerb des Doktorgrades der Zahnmedizin

an der Medizinischen Fakultät

der Ludwig-Maximilians-Universität zu München

Vorgelegt von

Ricarda Gudrun Bissinger

aus Brackenheim

2022

Mit Genehmigung der Medizinischen Fakultät

der Universität München

Berichterstatter:	Prof. Dr. med. dent. Jan Kühnisch
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Tag der mündlichen Prüfung:	02.06.2022

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Retrospektive Auswertung unfallbedingter Zahnhartsubstanzverletzungen

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München, den 12.07.2021

München den 29.06.2022 Ricarda Gudrun Bissinger

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Autoren: Ricarda Bissinger, Daniel David Müller, Marcel Reymus, Yegane Khazaei, Reinhard Hickel, Katharina Bücher, Jan Kühnisch

Journal: Clinical Oral Investigations

Veröffentlichungsdatum: 23.07.2020

DOI: 10.1007/s00784-020-03344-y

Publikationsdatum: Januar 2021, Volume 25, Issue 1, Seite 133-143

Publikation II

Titel: Survival analysis of adhesive reattachments in permanent teeth with crown fractures after dental trauma

Autoren: Ricarda Bissinger, Daniel David Müller, Reinhard Hickel, Jan Kühnisch

Journal: Dental Traumatology

Veröffentlichungsdatum: 12.11.2020

DOI: 10.1111/edt.12613

Publikationsdatum: April 2021, Volume 37, Issue 2, Seite 208-214

Darstellung des Eigenanteils

Publikation 1: Treatment outcomes after uncomplicated and complicated crown fractures in permanent teeth

Ricarda Bissinger, Daniel David Müller, Marcel Reymus, Yegane Khazaei, Reinhard Hickel, Katharina Bücher, Jan Kühnisch

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Publikation 2: Survival analysis of adhesive reattachments in permanent teeth with crown fractures after dental trauma

Ricarda Bissinger, Daniel David Müller, Reinhard Hickel, Jan Kühnisch

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Darstellung des Forschungsvorhabens

Ziel des vorliegenden Dissertationsprojektes war es, das Aufkommen, die Therapie und die Erfolgsrate therapeutischer Maßnahmen bei unfallbedingten Verletzungen der Zähne darzustellen. Vordergründiges Interesse erfuhr die Betrachtung von Zahnfrakturen und deren Management. Dazu sollten die verfügbaren Informationen von Patienten analysiert werden, welche an der Poliklinik für Zahnerhaltung und Parodontologie an der Ludwig-Maximilians-Universität München in einem Zeitraum von Januar 2004 bis Juni 2017 therapiert wurden. Im Rahmen dieser Studie wurden Patientendaten unfallbedingter Verletzungen der Zahnhartsubstanz, des Endodonts, des Parodonts, des Alveolarknochens und der Gingiva erfasst. Es wurden sowohl Milchzähne als auch bleibende Zähne berücksichtigt. Insgesamt konnten Daten von 898 Patienten (529 männliche/369 weibliche; Durchschnittsalter 16,9 Jahre; Altersspanne 0 – 86 Jahre) mit 1756 unfallbedingt verletzten Zähnen in die Studie einfließen.

Hauptziel des ersten Publikationsprojektes

Ziel der ersten Publikation war es, die Prognose von bleibenden Zähnen mit unkomplizierten Kronenfrakturen (ohne Beteiligung des Endodonts) und komplizierten Kronenfrakturen (mit Beteiligung des Endodonts) zu beschreiben. Hierbei sollten auch zusätzliche Luxationsverletzungen berücksichtigt werden. Das Überleben von Zähnen, der Pulpenvitalität und der restaurativer Therapiemaßnahmen wurden in Abhängigkeit zum Fraktur- und Luxationsmuster untersucht. Zudem sollte die klinische Eignung des Überkappungsmaterials MTA (Mineral Trioxid Aggregat) zur Vitalerhaltung der Pulpa nach Frakturen beschrieben werden.

Hauptziel des zweiten Publikationsprojektes

Ziel der zweiten Publikation war es, dass klinische Ergebnis der adhäsiven Wiederbefestigung von Zahnfragmenten (Reattachment) nach unkomplizierten und komplizierten Kronenfrakturen an bleibenden Zähnen zu untersuchen. Es sollte ermittelt werden, wie häufig Reattachments die Therapie der Wahl nach Kronenfrakturen waren, welche Überlebensraten für die wiederbefestigen Zahnfragmente vorlagen und an welchen Zähnen diese besonders häufig durchgeführt wurden.

Durch weitere Autoren wurde eine Publikation zur Betrachtung und Untersuchung traumatischer parodontaler Verletzungen veröffentlicht.[1]

Einleitung

Unfallverletzungen der Zähne und der benachbarten Gewebe können in allen Lebensphasen auftreten und sowohl Milchzähne als auch die bleibende Dentition betreffen. Mit einer Häufigkeit von 6,0% bis 58,6 % sind Unfallverletzungen der Zähne ein in der Bevölkerung oft vorkommendes Ereignis.[2–6] Durch Unfallverletzungen können fünf Gewebe im oralen Bereich verletzt werden: die Zahnhartsubstanz, das Endodont, das Parodont, der Alveolarknochen und die Gingiva (ZEPAG-Klassifikation).[7] Für den Zahnarzt besteht die Herausforderung diese variablen Verletzungsmuster korrekt zu diagnostizieren und einer adäquaten Notfall- und Langzeitversorgung zuzuführen. Ziel der vorliegenden Dissertation war es, das Spektrum an Unfallverletzungen an der Poliklinik für Zahnerhaltung und Parodontologie der Ludwig-Maximilians-Universität zusammenzufassen und einzelne Teilaspekte detailliert zu betrachten.

Material und Methoden

Für die vorliegende Untersuchung wurde ein Ethikantrag bei der zuständigen Kommission der medizinischen Fakultät der Ludwig-Maximilians- Universität München gestellt und dieser wurde positiv beschieden (Projektnummer 670-16).

Patienten. Das Patientengut der retrospektiven Untersuchung umfasst Patienten, welche in einem Zeitraum von Januar 2004 bis Juni 2017 aufgrund von unfallbedingten Zahnverletzungen an der Poliklinik für Zahnerhaltung und Parodontologie an der Ludwig-Maximilians-Universität München im Rahmen der Erstversorgung und/oder Weiterversorgung vorstellig wurden. Einschlusskriterium für die Studie war eine vollständig nachvollziehbare Dokumentation der Versorgung nach dem Trauma. Patienten, die aufgrund

von kariösem Zahnhartsubstanzverlust, Parodontitis, Zahnentwicklungsstörungen oder Aplasie behandelt wurden, wurden aus der Studie ausgeschlossen. Insgesamt konnten 898 Patienten (529 männliche/369 weibliche Patienten; Durchschnittsalter 16,9 Jahre; Altersspanne 0 – 86 Jahre) mit 1756 unfallbedingt verletzter Zähne (412 Milchzähne/1344 bleibende Zähne) in die Studie einfließen. Kronenfrakturen waren die am häufigsten dokumentierten Verletzungen im bleibenden Gebiss, mit insgesamt 489 Fällen unkomplizierter Kronenfrakturen (489/1344; 36,4% aller traumatisierter bleibender Zähne) und 127 Fällen komplizierter Kronenfrakturen (127/1344, 9,5% aller traumatisierter bleibender Zähne).

Diagnostik bei einem Zahnunfall. Jeder Patient, welcher sich nach einem Zahntrauma in der Zahnklinik vorstellte, wurde unverzüglich strukturiert untersucht und die Ergebnisse der Untersuchung wurden in einem Traumabogen dokumentiert. Nach Erhebung der Allgemeinanamnese, der Unfallanamnese und nach Ausschluss eines Schädel-Hirn-Traumas konnte mit der Untersuchung der Mundhöhle begonnen werden. Diese Untersuchung umfasst einen Sensitivitätstest mittels Kältespray, eine Abklärung der Perkussionsanfälligkeit, eine Beurteilung der Zahnbeweglichkeit und in der Regel eine apikale Röntgenaufnahme zur Erkennung/Ausschluss möglicher Wurzelfrakturen und zur Klärung des Status der Wurzelentwicklung. Die Zahnhartsubstanz, das Endodont, das Parodont, der Alveolarknochen und die Gingiva wurden auf Verletzungen hin untersucht. Die Diagnosen wurden auf der Grundlage klinischer und röntgenologischer Auswertungen unter Verwendung des anerkannten Klassifikationssystems von Andreasen und Andreasen gestellt.[8] Lag eine Verletzung der Zahnhartsubstanz vor so wurde zwischen Fällen von unkomplizierten Kronenfakturen, Frakturen der Zahnhartsubstanz die sich auf die Verletzung von Schmelz und/oder Dentin beschränken ohne Eröffnung der Pulpa, und komplizierte Kronenfrakturen,

Frakturen der Zahnhartsubstanz Schmelz und Dentin mit einer Eröffnung der Pulpa, unterschieden.[8] Darüber hinaus wurden auch zusätzlich diagnostizierte Verletzungen des Parodonts (Luxationsverletzungen) berücksichtigt.

Primärversorgung. Bei unkomplizierten und komplizierten Kronenfrakturen waren die wichtigsten therapeutischen Ziele die Erhaltung der Vitalität der Pulpa, insbesondere bei Zähnen mit unvollständiger Wurzelentwicklung, sowie die funktionelle und ästhetische Wiederherstellung des Zahnhartsubstanzdefektes. An Zähnen mit Schmelz-Dentin-Frakturen kommt es aufgrund der Eröffnung der Dentintubuli (Dentinwunde) zu einer Kommunikation mit der Pulpa, was eine Versorgung des Zahnhartsubstanzdefekts durch eine Restauration oder ein Reattachment indiziert. Insbesondere pulpanahe Kronenfrakturen und Kronenfrakturen mit Pulpaperforation wurden unverzüglich mit Maßnahmen zur Pulpenprotektion (indirekte Pulpenüberkappung), direkten Pulpenüberkappung oder einer Pulpotomie behandelt.

Die Behandlung von traumatischen Zahnhartsubtanzdefekten bedarf einer ergänzenden restaurativen Therapie. Das adhäsive Widerbefestigen des frakturierten Zahnfragments (Reattachment) ist die Therapie der ersten Wahl, wenn nach dem Unfall das gerettete Zahnfragment vorliegt. Bei fehlenden Zahnfragmenten wurde eine direkte Kompositfüllung appliziert. Alle verunfallten Zähne wurden gemäß den aktuellen klinischen Empfehlungen der International Association of Dental Traumatology behandelt.[9–12] Auch das nach erfolgter initialer zahnärztlicher Versorgung angebotene Monitoring orientiert sich an den Empfehlungen der International Association of Dental Traumatology .[9–12]

Datenmanagement. Für die strukturierte Zusammenstellung und Erfassung aller Fälle wurde ein Datenerfassungsbogen entwickelt, in welchen alle wesentlichen Informationen bezüglich

des Zahntraumas eingetragen wurden, um einen strukturierten Erfassungsprozess der Daten zu ermöglichen. 1. Patientencharakteristika (Alter, Geschlecht, Allgemeinanamnese), 2. Details des Zahntraumas (Datum, Uhrzeit, Ursache, Umstände und Ort des Unfalls Erstunfall/Wiederholungstrauma, Diagnosen, Details der initialen zahnärztlichen Versorgung) und 3. Ergebnisvariablen (Ergebnisse des Kontrollbesuchs, einschließlich Komplikationen, z.B. Avitalität der Pulpa oder Verlust der Restauration/Reattachment). Um Details im Zusammenhang mit dem Zahntrauma zu ermitteln und/oder zu überprüfen wurden zahnärztliche und/oder medizinische Berichte oder Fotos als zusätzliche Informationsquellen verwendet. Diese fallbezogenen Informationen wurden anschließend digitalisiert (EpiData Software, Version: V4.0.2.101, EpiData Association, Odense, Dänemark). Der digitale Datensatz wurde zunächst über eine csv-Datei zur weiteren Analyse in eine MS Excel-Tabelle (Microsoft Office 365 Excel, Version 1804, Mircosoft Corporation, Redmond, WA, USA) übertragen. Die deskriptive Analyse der Daten wurde mit Microsoft Excel und SPSS Statistics for Windows (SPSS Inc., Version 21.0.1, IBM Company, Armonk, NY, USA) durchgeführt. Die explorative statistische Analyse wurde mit R-Software (Version 3.6.0, R Development Core Team, Wien, Österreich) ausgeführt.

Ergebnisse

Publikation 1

Aus dem vorliegenden Patientengut waren 434 Patienten (253 männliche Patienten/181 weibliche Patienten; Durchschnittsalter 20,7 Jahre; Altersspanne 6 - 86 Jahre) mit insgesamt 616 permanenter Zähne von einer traumatischen Verletzung der Zahnhartsubstanz (unkomplizierte oder komplizierte Kronenfraktur) betroffen (616/1344 Zähne; 45,8% aller traumatisierten Zähne im bleibenden Gebiss). Aus der Gruppe mit (un)komplizierten Kronenfrakturen erhielten 178 Patienten (41,0%) eine zahnärztliche Notfallversorgung in der Poliklinik für Zahnerhaltung und Parodontologie an der Ludwig-Maximilians-Universität München. 222 Patienten (51,2%) wurden der Abteilung für konservierende Zahnheilkunde und Parodontologie zur weiteren Behandlung oder zum Monitoring nach der initialen zahnärztlichen Versorgung durch einen externen Zahnarzt überwiesen. 4 Patienten (0,9%) baten um eine Zweitmeinung und bei 30 Patienten (6,9%) fehlte diese Information. Schließlich wurden 489 unkomplizierte Kronenfrakturen (419 ohne Luxation/70 mit Luxation) und 127 komplizierte Kronenfrakturen (101 ohne Luxation/26 mit Luxation) im bleibenden Gebiss identifiziert und im Rahmen des Publikationsvorhabens analysiert. Die oberen medialen Schneidezähne waren die am häufigsten frakturierten Zähne (71,3%; N=439/616), gefolgt von den oberen lateralen Schneidezähnen (17,7%; N=109/616), Molaren und Prämolaren (5.4%; N=33/616), die Schneidezähne im Unterkiefer (3,9%; N=24/616) und die Eckzähne (1,8%; N=11/616) waren deutlich seltener traumatisiert. Im Alter zwischen 6 und 16 Jahren wurde bei Patienten eine Häufung von Zahnfrakturen registriert (41,6%; N=256/616). Die mittlere Beobachtungszeit für alle Zähne mit Kronenfrakturen betrug 522,3 Tage (0 - 4837 Tage; 896,0 Tage Standardabweichung).

In Fällen unkomplizierter Kronenfrakturen betrug die Überlebensrate der Zähne 100%. In der Gruppe der komplizierten Kronenfrakturen wurden 5,5% (N=7/127) der Zähne im Rahmen der initialen zahnärztlichen Versorgung extrahiert. Die Gruppe der unkomplizierten Kronenfrakturen ohne Luxation (N=419/489) machte in der vorliegenden Population den größten Anteil aus, gefolgt von komplizierten Kronenfrakturen ohne Luxation(N=101/127). Beide Entitäten zeigten hohe klinische Erfolgsraten in Bezug auf das Überleben der Pulpenvitalität und der Restauration. Bei 82,3 % (N=345/419) bzw. 72,3 % (N=73/101) der Zähne wurde kein Verlust der Pulpenvitalität und Restauration (direkte Kompositfüllung oder Reattachment) beobachtet. Die Erfolgsrate nahm erheblich ab in Fällen zusätzlicher Luxationsverletzungen. Betrachtet man den Vitalitätsverlust, so überlebten 27,1% (N=19/70) der Pulpen in der Gruppe der unkomplizierten Kronenfrakturen mit zusätzlicher Luxation nicht, eine ähnliche Größenordnung (26,9%; N=7/26) wurde bei komplizierten Kronenfrakturen mit zusätzlichen Luxationsverletzungen dokumentiert. Die Anteile der avitalen Pulpen betrugen 6,2% bzw. 13,9% bei Patienten mit unkomplizierten und komplizierten Kronenfrakturen ohne Luxation. Eine zusätzliche Luxation erwies sich in der Cox-Proportional-Hazard-Regressionsanalyse bei unkomplizierten Kronenfrakturen als signifikant nachteilig für das Überleben der Pulpa.

Die ausgewerteten Daten wurden auch bezüglich der klinischen Eignung von MTA als direktes Überkappungsmaterial nach komplizierten Kronenfrakturen untersucht. Dabei konnte herausgestellt werden, dass mehr Pulpen überlebten, nachdem diese mit MTA behandelt worden sind (80,5%; N=33/41) im Gegensatz zu Pulpen aus der Gruppe nach Überkappung mit Kalziumhydroxid Präparat (71,0%; N=22/31). In der Regressionsanalyse zeigte sich allerdings keine Signifikanz.

Betrachtet man den Verlust der Restauration (direkte Füllung oder Reattachment) lässt sich der Trend beschreiben, dass es in der Gruppe der komplizierten Kronenfrakturen häufiger zu einem Verlust kommt (19,7%; N=25/127) als in der Gruppe der unkomplizierten Kronenfrakturen (11,0%; N=54/489). Direkte Füllungen verzeichneten einen größeren klinischen Erfolg als Reattachments.

Publikation 2

Im Rahmen der zweiten Publikation wurde der Fokus der Untersuchung auf das Wiederbefestigen von Zahnfragmenten (Reattachments) als restaurative Therapie nach unkomplizierten und komplizierten Kronenfrakturen in bleibenden Zähnen gelegt.

Insgesamt wurden 109 Patienten (70 männliche Patienten/39 weibliche Patienten; Durchschnittsalter 15,7 Jahre; Altersspanne 6 - 64 Jahre) mit 135 wiederbefestigten Fragmenten, Mittelwert von 1,2 wiederbefestigten Zahnfragmenten pro Unfall, konstatiert. 84 Reattachments wurden in Zähnen mit unkomplizierten Kronenfrakturen (17,2%; N=84/489) durchgeführt und 51 Reattachments in Zähnen mit komplizierten Kronenfrakturen (40,2%; N=51/127). Die mittleren Schneidezähne des Oberkiefers waren die Zähne bei denen Reattachments am häufigsten durchgeführt wurden (88,2%; N=119/135) gefolgt von den seitlichen Schneidezähnen des Oberkiefers (9,6%; N=13/135). Oberkiefer-Prämolaren (1,5%; N=2/135) und die Schneidezähne des Unterkiefers (0,7%; N=1/135) wurden weniger häufig mit einem Reattachment versorgt. Im Fall von fehlenden Anteilen des Zahnfragments wurden diese mit einer ergänzenden direkten Restauration vervollständigt, dies war bei insgesamt 13,3% (N=18/135) der Reattachments dokumentiert. Die mittlere Beobachtungszeit betrug 608,2 Tage (0 - 4837 Tage; Standardabweichung 983,1 Tage).

77,4% (N=65/84) und 66,6% (N=34/51) der primär durchgeführten Reattachments bei unkompliziert bzw. kompliziert frakturierten Zähnen blieben über den gesamten Beobachtungszeitraum erfolgreich. Die wiederbefestigten Fragmente lösten sich bei 22,6% der unkomplizierten Kronenfrakturen (N=19/84) und bei 33,3% der komplizierten Kronenfrakturen (N=17/51). Die mittlere Beobachtungszeit der Reattachments bis zum Verlust des wiederbefestigten Fragments betrug 240,8 Tage (Standardabweichung 274,2 Tage).

Nach Verlust des initial angebrachten Reattachments wurden 52,8% (N=19/36) mit einer zweiten Wiederbefestigung des Zahnfragments (Re-Reattachment) behandelt. Die zweiten Wiederbefestigungen (Re-Reattachment) hatten eine Erfolgsrate von 68,4% (N=13/19). Im Falle eines zweiten Verlusts des Fragments wurden 33,3% (N=2/6) mit einer dritten Wiederbefestigung des Zahnfragments (Re-Rettachment) behandelt, und diese hatten eine Erfolgsrate von 100% (N=2/2). Werden alle Zähne mit einem Reattachment berücksichtigt, konnten 84,4% der Zähne erfolgreich mit einer adhäsiven Wiederbefestigung des frakturierten Fragments behandelt werden (N=114/135).

Diskussion

Diese retrospektive Studie liefert Langzeitdaten zur zahnärztlichen Behandlung von unfallbedingten Verletzungen der Zahnhartsubstanz bleibender Zähne. Den größten Anteil der Zahnverletzungen des bleibenden Gebisses wiesen unkomplizierte und komplizierte Kronenfrakturen aus, die 45,8% (N=616/1344) aller traumatischer Ereignisse im vorliegenden Patientengut ausmachten. Diese Erkenntnisse entsprechen den Ergebnissen anderer Veröffentlichungen.[5,13,14] Die Schlüsselinformation aus dieser Studie ist, dass Kronenfrakturen

und ihre klinische Behandlung im Allgemeinen mit akzeptabel hohen Erfolgsraten verbunden waren. Dennoch wurde in einigen Fällen einem Verlust der Pulpenvitalität und/ oder der direkten Restauration/des Reattachments verzeichnet.

Eine häufige Komplikation nach unkomplizierten oder komplizierten Kronenfrakturen ist ein Verlust der Pulpenvitalität, der häufiger in Fällen mit zusätzlicher Luxationsverletzung festgestellt wurde, diese Kombination erwies sich bei unkomplizierten Kronenfrakturen als signifikant nachteilig für das Überleben der Pulpenvitalität. Dieser Befund lässt sich leicht durch zwei Faktoren erklären. Erstens führt der Zahnhartsubstanzverlust zu einer Perforation von Dentintubuli. Zweitens kann die Pulpenvitalität durch die vorübergehende oder definitive Unterbrechung der Blutversorgung am Foramen apicale, die typischerweise mit Luxationsverletzungen einhergeht, geschädigt werden. Beide Szenarien können potenziell zu einem Verlust der Pulpenvitalität nach einem Zahnunfall führen. Bei der Betrachtung unserer Daten wurden beachtenswerte Trends beobachtet. Die höchste Pulpenvitalitätsüberlebensrate wurde bei Zähnen mit unkomplizierten Frakturen ohne Luxation dokumentiert (93,8%), gefolgt von komplizierten Frakturen ohne zusätzliche Luxationsverletzungen (86,1%). Diese Zahlen scheinen identisch oder überdurchschnittlich hoch im Vergleich zu früher publizierten Daten zu sein, die in bis zu 24% aller Fälle einen Vitalitätsverlust berichteten. [14–16] Der Anteil endodontischer Komplikationen nahm in unserer Stichprobe zu, wenn zusätzlich eine Luxation diagnostiziert wurde. Etwa einer von vier Zähnen verlor innerhalb des Beobachtungszeitraums seine Vitalität, was ein biologisch plausibles Ergebnis ist und die klinische Relevanz der Diagnostik einer zusätzlichen Luxationsverletzung hervorhebt. Interessanterweise wurden bisher nur wenige und heterogene Daten aus vergleichbaren Studien veröffentlicht, die günstigere, gleiche oder ungünstigere Ergebnisse berichten.[13,14,17–20]

Eine weitere relevante Frage für Zahnmediziner betrifft den möglichen Zeitpunkt, an dem ein endodontisches Versagen auftreten kann. Hier traten 64,3 bis 89,5% aller dokumentierten endodontischen Ereignisse innerhalb des ersten Jahres nach dem Zahnunfall auf. Mindestens 78,6% aller endodontischen Ereignisse wurden zwei Jahre nach dem Unfall diagnostiziert. Basierend auf diesen Ergebnissen scheint eine vierteljährliche Kontrolluntersuchung von Kronenfrakturen über zwei Jahre hinweg indiziert zu sein. Die Recall-Intervalle können sich nach zwei Jahren verlängern, da danach nur wenige endodontische Komplikationen auftraten.

Eine weitere häufig diagnostizierte Komplikation war der Verlust der restaurativen Therapie (direkte Restauration oder Reattachment). Interessanterweise waren die Anteile der restaurativen Komplikationen in der Gruppe mit komplizierten Kronenfrakturen höher als in der Gruppe mit unkomplizierten Kronenfrakturen. Diese Zahlen erklärten sich dadurch, dass komplizierte Kronenfrakturen häufig mit einem größerem Hartsubstanzdefekt verbunden sind, der eine umfangreichere Versorgung (Maßnahmen zur Pulpabehandlung wie direkte Überkappung, Pulpotomie oder Wurzelkanalbehandlung) erfordert als unkomplizierte Kronenfrakturen. Im Gegensatz dazu wies die restaurative Versorgung bei Zähnen mit unkomplizierten Kronenfrakturen die höchste Überlebenswahrscheinlichkeit auf. Eine weitere klinisch relevante Erkenntnis aus den Auswertungen war, dass direkte Restaurationen zu höheren Überlebenswahrscheinlichkeiten führten im Vergleich zur Wiederbefestigung von Zahnfragmenten (Reattachment). Dieser Beobachtung muss sorgfältig interpretiert werden, da die Wiederbefestigung von Kronenfragmenten aufgrund ihrer minimalen Invasivität und natürlichen Ästhetik als die Restaurationsmethode der Wahl angesehen werden sollte. Im Gegensatz zu diesem Befund ist die Verwendung von direkten Komposit-Restaurationen mit höheren Überlebensraten verbunden, da die Möglichkeit besteht, dass die

Restaurationsränder angeschrägt werden, was die Anhaftung im Zahnschmelz vergrößert. Im Hinblick auf diese wichtigen klinischen Variablen sollten die dokumentierten Überlebensraten nicht dahingehend fehlinterpretiert werden, dass direkte Restaurationen in der primären zahnärztlichen Traumaversorgung gegenüber dem Wiederbefestigen von Zahnfragmenten (Reattachment) bevorzugt werden.

Die Stärke der vorliegenden retrospektiven, longitudinalen Fall-Kontroll-Studie liegt in der vergleichsweise großen Stichprobengröße und der detaillierten Analyse der Daten, einschließlich der Beurteilung über das Vorhandensein oder Nichtvorhandensein einer zusätzlichen Luxationsverletzung. Darüber hinaus wurden alle eingeschlossenen Patienten nach der Jahrtausendwende behandelt, was darauf hindeutet, dass die Behandlungsentscheidungen auf der Grundlage der kürzlich veröffentlichten klinischen Leitlinie getroffen wurden.[9–12]

Bei der Betrachtung möglicher Einschränkungen dieser praxisorientierten Studie muss erwähnt werden, dass in dieser Untersuchung klinische Daten retrospektiv ohne eine zusätzliche, studienintensive klinische Untersuchung der Patienten erhoben wurden. Folglich ist dieses Studiendesign in Bezug auf Ein- und Ausschlusskriterien, Datenerfassung oder Recall-Intervalle weniger zuverlässig als eine prospektiv konzipierte klinische Studie.

Zusammenfassung

Die Zielsetzung des Dissertationsprojektes war es, das therapeutische Management von Frakturverletzungen der Zahnhartsubstanz unter zusätzlicher Berücksichtigung von Luxationsverletzungen im bleibenden Gebiss zu untersuchen und im Rahmen einer retrospektiven Auswertung zu analysieren.

Ein wichtiges Ergebnis der retrospektiven Studie war es, dass sowohl unkomplizierte als auch komplizierte Kronenfrakturen in Bezug auf das Überleben von Pulpenvitalität und Restauration eine hohe Erfolgsrate aufweisen. Im Fall von zusätzlichen Luxationsverletzungen sank die Überlebensrate der Pulpenvitalität und von Restauration sowohl bei unkomplizierten als auch bei komplizierten Kronenfrakturen.

Darüber hinaus können beide Frakturmuster mit einer guten Erfolgsrate mit Reattachments versorgt werden, sofern diese vorliegen. Sollten sich wiederbefestige Fragmente lösen, geht die Wiederholung des gleichen klinischen Vorgehens gleichfalls mit einer hohen Erfolgsrate einher.

Abstract

The objective of the dissertation project was to investigate the therapeutic management of fracture injuries of the dental hard tissue with additional consideration of luxation injuries in the permanent dentition and to analyse it in a retrospective evaluation.

An important finding of the retrospective study was that both uncomplicated and complicated crown fractures had a high success rate in terms of pulp vitality and restoration survival. In the case of additional luxation injuries, the survival rate of pulp vitality and restoration decreased in both uncomplicated and complicated crown fractures.

In addition, both fracture patterns can be restored with a good success rate with reattachments if available. Should reattached fragments detach, repetition of the same clinical procedure is similarly associated with a high success rate.

Veröffentlichung I

Clinical Oral Investigations
https://doi.org/10.1007/s00784-020-03344-y

ORIGINAL ARTICLE

Treatment outcomes after uncomplicated and complicated crown fractures in permanent teeth

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Received: 14 October 2019 / Accepted: 14 May 2020

Abstract

Objectives The objectives of this retrospective clinical study were to describe characteristics of crown fractures in permanent teeth and to investigate the survival of pulp vitality and restorations in uncomplicated and complicated crown fractures.

Materials and methods This retrospective study collected information from patients suffering from dental trauma who were treated between January 2004 and June 2017. The study population consisted of 434 patients (253 males/181 females; mean age 20.7 years) with 489 uncomplicated and 127 complicated crown fractures. The Kaplan-Meier survival curves and Cox proportional hazard regression analyses were performed to explore the data statistically.

Results The mean observation time was 522 days. Uncomplicated crown fractures without luxation showed a higher success rate of 82.3% (345/419) than complicated crown fractures without luxation (72.3%, 73/101). An additional luxation in uncomplicated crown fractures resulted in significantly reduced success rates in terms of survival of the pulp and restoration. Direct restorations survived significantly better independent of the fracture mode than did adhesively reattached crown fragments. No superiority of mineral trioxide aggregate or calcium hydroxide as pulp capping agent in complicated crown fractures was documented. Approximately 85.5% of all complications occurred within 2 years after the accident.

Conclusion The treatment of crown fractures resulted mostly in successful outcomes and only a moderate number of complications were observed.

Clinical relevance Primary dental management of crown fractures should follow recently published clinical guidelines, and close monitoring over at least 2 years seems to be justified.

Keywords Complicated crown fracture · Dental trauma · Prognosis · Survival analysis · Treatment · Uncomplicated crown fracture

Introduction

Dental trauma is a frequent incident in permanent dentition and can occur in all stages of life, with increased numbers documented in the first and second decades of life [1, 2]. When considering the spectrum of injuries, crown fractures with or without pulp exposure are the most frequently recorded types of dental trauma [3, 4]. Numerous case reports and descriptive analyses have been published over the past few decades, which have mostly illustrated the clinical characteristics [5–8]. Unfortunately, few current longitudinal investigations [8–10] have included a large sample size or considered additional diagnoses, e.g. luxation or pulp exposure, and the corresponding treatments. Surprisingly, limited studies have been published on the clinical outcomes of bioactive cements, e.g. mineral trioxide aggregate (MTA), for pulp capping in teeth with complicated crown fractures [11], despite this material being widely used in daily dental practice. Therefore, information about its clinical performance is needed. Another unexpected finding was that only scarce longevity data are available for direct composite restoration in fractured anterior teeth [12]. Considering the previously mentioned gaps in knowledge, the objectives of this retrospective clinical

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Published online: 23 July 2020

study were to describe characteristics of crown fractures in permanent teeth and to provide longevity information about the survival of teeth, pulp, and restorations in relation to the fracture and luxation patterns. The null hypothesis formulated that the survival of pulp vitality and restoration would be equally distributed in relation to the type of injury.

Materials and methods

This retrospective study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Human Ethics Committee of the Medical Faculty of the Ludwig-Maximilians-University, Munich (Project no. 670-16).

Study population

This retrospective study collected information from patients suffering from dental trauma who were treated at the Department of Conservative Dentistry and Periodontology at Ludwig-Maximillians-University in Munich, Germany, between January 2004 and June 2017. Patients with a diagnosis of dental trauma in the primary or permanent dentition were included. Additional inclusion criteria were complete dental records on patient characteristics (e.g. age, gender) and detailed information about the traumatized tooth and corresponding treatment. Patients who received conservative treatment due to caries, periodontitis, developmental defects or aplasia were excluded. Finally, 898 patients (529 males/369 females; mean age of 16.9 years; range 0–86 years) with 1756 traumatized teeth (1344 permanent teeth/412 primary teeth; mean of 2.0 injured teeth per accident) were eligible for inclusion.

Diagnostic and treatment principles at the Department of Conservative Dentistry and Periodontology

Key issues of the diagnostic and treatment protocols are described below. Importantly, any treatment decision was based on individual and standardized clinical and radiographic examinations. These examinations included sensitivity testing (method of first choice: refrigerant spray; method of second choice: electric pulp tester), an evaluation of the susceptibility to percussion, an assessment of tooth mobility and a compulsory apical radiograph for the detection of possible root fractures and for clarification of the status of root development. Furthermore, the dental hard tissue, endodontium, periodontium, alveolar bone and gingiva [13] were consistently assessed during the initial and recall visits. Diagnoses were made upon clinical and radiographic evaluations using the well-accepted classification system by Andreasen and Andreasen [14]. When crown fractures occurred, cases with no direct pulp exposure (uncomplicated crown fracture) and cases with pulp exposure (complicated crown fracture) were distinguished.

While uncomplicated crown fractures received mostly no indirect pulp treatment, the pulp tissue needed to be urgently preserved when the pulp was exposed. Here, bioactive cements, e.g. mineral trioxide aggregate (ProRoot MTA, Dentsply Sirona, York, PA, USA; Medcem MTA, Medcem GmbH, Wien, Austria), or an aqueous calcium hydroxide suspension was used for direct pulp capping. In general, for managing (un)complicated crown fractures, the clinicians followed the latest clinical guidelines, which were slightly modified during the study period [15–18]. Furthermore, in several cases, a root canal treatment was performed by the dentist who assumed the initial dental trauma care. Crown fractures with exposed pulp and fractures that were located near a pulp were immediately—at least on the same day the patient presented—treated with direct pulp capping or measurements for pulp protection (indirect pulp capping), respectively.

The management of dental defects in the hard tissue requires a deliberate restorative strategy. Two possible treatments were employed. First, if the fractured tooth fragment was saved, then the adhesive reattachment of the fragment [19] was the treatment procedure of choice. Second, if the fragment was lost, a direct composite restoration was applied. Again, the restorative management of (un)complicated crown fractures followed the latest clinical guidelines [15–18].

All diagnostic and therapeutic information were consistently recorded during the patient management on a separate case report form. After emergency treatment, each patient was offered a recall/monitoring visit at the appropriate interval according to the diagnosis at the Department of Conservative Dentistry and Periodontology.

Standardized review of patient records

Two dental professionals (RB and DM) identified patients with any dental trauma based on the paper-based and electronic dental documentation records. Patients were considered if they presented in the Department of Conservative Dentistry and Periodontology during the interval from January 2004 to June 2017. A case report form was developed in which all relevant information regarding the dental trauma was entered to enable a structured data acquisition process: (1) patient characteristics (gender, age); (2) details of the dental trauma and its initial management (date, time, cause, circumstances and location of the accident, diagnoses, details of initial dental care); and (3) outcome variables (results from the monitoring visit, including complications, e.g. pulp vitality and survival of the restoration). Dental and/or medical reports or photographs were used as additional sources of information to obtain and/or verify details related to the dental trauma. All

information was electronically acquired using data entry and documentation software (EpiData Software, version: V4.0.2.101, EpiData Association, EpiData - Comprehensive Data Management and Basic Statistical Analysis System, Odense, Denmark). If all the required information was not available or was misleading, the practitioner(s) was/were questioned to complete the missing information. In cases of diverging information, the study group (RB, DM and JK) reassessed the available data and discussed their points until a consensus was reached. In the case of undocumented details, the variable was missing.

Statistical analysis

The whole dataset was initially transferred to an MS Excel sheet (Microsoft Office 365 Excel, version 1804, Redmond, WA, USA) via a csv file for further analysis. The descriptive analysis of the data was undertaken with Microsoft Excel and SPSS Statistics for Windows, Version 21.0.1 (SPSS Inc., an IBM Company, Armonk, NY, USA). Explorative statistical analysis was performed using R software (version 3.6.0, R Development Core Team, Vienna, Austria). The significance level was set at $\alpha = 0.05$ with a 95% confidence interval. Survival curves were generated by Kaplan-Meier estimators [20]. For the survival analysis of the pulp vitality and the restorations, injuries were grouped into (un)complicated crown fractures with and without luxation. An assessment of the proportion of pulps and restorations that did not survive in a certain period after trauma and its treatment were linked to clinical situations indicating failure. The loss of pulp vitality was achieved when a tooth was classified as non-vital—with or without the presence of an apical inflammation—and was trepanned or received a root canal treatment. Restorations were recorded as failed if they were replaced because of loss or insufficiency, according to the FDI recommendations for the evaluation of direct restoration [21, 22]. In cases of reattached tooth fragments, failures were documented when the fragment was lost and was adhesively reattached. Differences in the survival rate were assessed by applying the log-rank test. Furthermore, a Cox proportional hazard regression analysis was performed to investigate the influence of the variables of interest on pulp and restoration survival.

Results

Of the whole study population, 434 patients (253 males/181 females; mean age of 20.7 years; range 6–86 years) with a total of 616 teeth were affected by a(n) (un)complicated crown fracture (616/1344 teeth; 45.8% of all traumatized teeth in the permanent dentition). Of this population, 178 patients (41.0%) received emergency dental care at the Department of Conservative Dentistry and Periodontology, 222 patients (51.2%) presented to the Department of Conservative Dentistry and Periodontology for further treatment or monitoring after treatment by an external (dental) healthcare provider (mostly the Department of Oral and Maxillofacial Surgery), 4 patients (0.9%) requested a second opinion and the information was missing for 30 patients (6.9%). In detail, 489 (419 without luxation/70 with luxation) and 127 permanent teeth (101 without luxation/26 with luxation) were identified with an uncomplicated and complicated crown fracture, respectively. The upper central incisors were the most frequently fractured teeth in the permanent dentition ($N = 439$, 71.3%), followed by the upper lateral incisors ($N = 109$, 17.7%). Posterior teeth ($N = 33$, 5.4%), incisors in the mandible ($N = 24$, 3.9%) and canines ($N = 11$, 1.8%) were less frequently traumatized. An observable accumulation of fractured teeth was registered in patients aged between 6 and 16 years ($N = 256$; 41.6%). The mean observation time for all permanent teeth with crown fractures was 522.3 days (0–4837 days, 896.0 days standard deviation).

In cases of uncomplicated crown fractures, the tooth survival rate was 100%. In the group of complicated crown fractures, 5.5% ($N = 7$) of teeth were extracted.

The group of uncomplicated crown fractures without luxation (Table 1) comprised the largest proportion in the present sample, followed by complicated crown fractures without luxation (Table 2). Both entities showed high clinical success rates in terms of survival of pulp vitality and restoration. No loss of pulp vitality or restoration was observed in 82.3% ($N = 345/419$) and 72.3% ($N = 73/101$) of the teeth, respectively (Tables 1 and 2). In cases of additional luxation, the success rate decreased significantly (Table 3). When considering the loss of vitality, 27.1% of the pulps did not survive in the group of uncomplicated crown fractures with an additional luxation (Table 1); a similar order of magnitude (26.9%) was documented for complicated crown fractures (Table 2). The proportions of non-vital pulps amounted to 6.2% and 13.9% in the subjects with uncomplicated and complicated crown fractures without luxation, respectively. An additional luxation was found to be a significant disadvantageous factor for pulp survival in the Cox proportional hazard regression analysis in uncomplicated crown fractures. Interestingly, restorations on uncomplicated fractured teeth with an additional luxation performed better than those on non-dislocated teeth (Table 3).

A separate analysis investigated the outcomes of the use of MTA and calcium hydroxide as pulp capping agents in patients with complicated crown fractures. Regarding the percent loss of vitality, more vital pulps (80.5%, $N = 33/41$) were observed in the MTA group than in the calcium hydroxide group (71.0%, $N = 22/31$). When considering the results from the Cox proportional hazard regression analysis, a non-significant influence of the clinical pulp treatment was documented (Table 3).

Table 1 Overview of success rates and complication rates of pulp and restorative treatments for uncomplicated crown fractures with and without accompanying luxation injuries

Diagnosis	Pulp treatment	Restorative treatment	Success		Complications					
					Loss of vitality		Loss of restoration		Total	
			N	%	*N*	%	*N*	%	*N**	%
Uncomplicated crown fracture without luxation (*N* = 419)	Indirect pulp capping	Reattachment (*N* = 6)	4	66.7	2	33.3	–	–	2	33.3
		Direct restoration (*N* = 20)	13	65.0	3	15.0	5	29.4	7	35.0
	No additional pulp protection	Reattachment (*N* = 67)	48	71.6	1	1.5	18	26.9	19	28.4
		Direct restoration (*N* = 298)	253	83.6	19	6.4	28	9.4	45	15.1
		No restoration (*N* = 28)	27	96.4	1	3.6	–	–	1	3.6
		∑	345	82.3	26	6.2	51	12.2	74	17.7
Uncomplicated crown fracture with luxation (*N* = 70)	Indirect pulp capping	Reattachment (*N* = 3)	3	100.0	–	–	–	–	–	–
		Direct restoration (*N* = 4)	2	50.0	1	25.0	1	25.0	2	50.0
	No additional pulp protection	Reattachment (*N* = 8)	6	75.0	1	12.5	1	12.5	2	25.0
		Direct restoration (*N* = 46)	29	63.0	16	34.8	1	2.2	17	37.0
		No restoration (*N* = 9)	8	88.9	1	11.1	–	–	1	11.1
		∑	48	68.6	19	27.1	3	4.3	22	31.4

*One tooth may have multiple complications

A higher proportion of lost restorations was observed in the group with complicated crown fractures than in the group with uncomplicated crown fractures (Tables 1 and 2). Furthermore, direct restorations performed significantly better than reattached tooth fragments independent of the mode of fracture (Table 3).

The mean time interval of pulp failure was 338.8 days (standard deviation 735.9 days) and 280.9 days (sd 371.1 days) in the groups with uncomplicated and complicated crown fractures, respectively. In cases of a restoration failure, the corresponding mean intervals were 469.2 days (sd 723.9 days) for uncomplicated crown fractures and 310.4 days (sd 357.3 days) for complicated crown fractures. Overall, 85.5% of all complications—loss of pulp vitality and/or restoration—occurred within the first 2 years after the accident (Table 4). The Kaplan-Meier curves which estimate survival from lifetime data are shown in Figs. 1 and 2.

Discussion

This retrospective clinical study provides detailed data about the outcomes and prognosis of dental management for fractured permanent teeth and represents an update of an earlier report [9]. Uncomplicated and complicated crown fractures, representing 45.8% (*N* = 616/1344 teeth) of all traumatic events in the present sample, comprised the largest proportion of dental injuries of the permanent dentition, consistent with the literature [23]. The key information from this study is that crown fractures and their clinical management were generally linked to acceptably high success rates. Nevertheless, in some situations, a loss of pulp vitality and/or restoration will occur. Therefore, the initially formulated hypothesis needs to be rejected.

A common complication of endodontic treatment is a loss of pulp vitality, which was more frequently detected in cases with additional luxation (Tables 1 and 2); this association was found to be significant in uncomplicated crown fractures (Table 3). This finding is easily explained by two factors. First, it might be caused by the traumatization of the coronal dentin-pulp system, resulting in a perforation of dentin tubules or in the direct opening of the pulp; in both situations, the odontoblast cells might be negatively affected. Second, the pulp vitality might be damaged due to the temporary or definitive interruption of the blood supply at the foramen apicale, which is typically linked to luxation injuries. Both scenarios might be associated with a potential loss of pulp vitality after the dental trauma. When viewing our data in this context, notable trends were observed (Tables 1 and 2). The highest pulp survival rate was documented in teeth with uncomplicated fractures without luxation (93.8%, Table 1), followed by complicated fractures without an additional luxation (86.1%, Table 2). These numbers appear to be identical to or above-average compared to previously published data, which indicated loss of vitality in up to 24% of all cases [3, 11, 24]. The proportion of endodontic complications increased in our sample when a luxation was additionally diagnosed; approximately one of four teeth lost its vitality within the observation

Table 2 Overview of success rates and complication rates of pulp and restorative treatments for complicated crown fractures with and without accompanying luxation injuries

Diagnosis	Pulp treatment		Restorative treatment	Success		Complications					
						Loss of vitality		Loss of restoration		Total	
				N	%	*N*	%	*N*	%	*N**	%
Complicated crown fracture without luxation (*N* = 101)	Direct pulp capping	MTA	Reattachment (*N* = 13)	9	69.2	–	–	4	30.8	4	30.8
			Direct restoration (*N* = 9)	6	66.7	3	33.3	–	–	3	33.3
		$Ca(OH)_2$	Reattachment (*N* = 9)	4	44.4	4	44.4	3	33.3	5	55.6
			Direct restoration (*N* = 14)	9	64.3	3	21.4	3	21.4	5	35.7
	Pulpotomy	MTA	Reattachment (*N* = 5)	3	60.0	1	20.0	2	40.0	2	40.0
			Direct restoration (*N* = 2)	1	50.0	–	–	1	50.0	1	50.0
		$Ca(OH)_2$	Reattachment (*N* = 4)	2	50.0	2	50.0	1	25.0	2	50.0
			Direct restoration (*N* = 0)	–	–	–	–	–	–	–	–
	Root canal treatment		Reattachment (*N* = 7)	5	71.4	–	–	2	28.6	2	28.6
			Direct restoration (*N* = 17)	14	82.4	–	–	3	17.6	3	17.6
	Not specified		Reattachment (*N* = 3)	2	66.7	1	33.3	–	–	1	33.3
			Direct restoration (*N* = 11)	11	100.0	–	–	–	–	–	–
	Extraction		(*N* = 7)	7	100.0	–	–	–	–	–	–
			∑	73	72.3	14	13.9	19	18.8	28	27.7
Complicated crown fracture with luxation (*N* = 26)	Direct pulp capping	MTA	Reattachment (*N* = 5)	1	20.0	1	20.0	4	80.0	4	80.0
			Direct restoration (*N* = 4)	1	25.0	3	75.0	1	25.0	3	75.0
		$Ca(OH)_2$	Reattachment (*N* = 0)	–	–	–	–	–	–	–	–
			Direct restoration (*N* = 2)	2	100.0	–	–	–	–	–	–
	Pulpotomy	MTA	Reattachment (*N* = 3)	3	100.0	–	–	–	–	–	–
			Direct restoration (*N* = 0)	–	–	–	–	–	–	–	–
		$Ca(OH)_2$	Reattachment (*N* = 2)	1	50.0	–	–	1	50.0	1	50.0
			Direct restoration (*N* = 0)	–	–	–	–	–	–	–	–
	Root canal treatment		Reattachment (*N* = 0)	–	–	–	–	–	–	–	–
			Direct restoration (*N* = 5)	5	100.0	–	–	–	–	–	–
	Not specified		Reattachment (*N* = 0)	–	–	–	–	–	–	–	–
			Direct restoration (*N* = 5)	2	40.0	3	60.0	–	–	3	60.0
	Extraction		(*N* = 0)	–	–	–	–	–	–	–	–
			∑	15	57.7	7	26.9	6	23.1	11	42.3

*One tooth may have multiple complications

period (Tables 1 and 2), which is a biologically plausible finding and illustrates the clinical relevance of an additional luxation injury. Interestingly, few and heterogeneous data have been published from comparable studies to date and have documented more favourable [8], equal [8] or unfavourable results [3, 5–7, 10].

When considering the clinical success of pulp therapy in relation to the capping material, MTA tended to provide better but non-significant clinical results than calcium hydroxide in the case of indicated pulpotomies. Interestingly, an inverse trend was documented in the case of direct pulp capping. Nevertheless, no superiority of a pulp-maintaining procedure can be derived from the Cox proportional hazard regression analysis of the current data (Table 3). When considering the clinical advantages of bioactive cements [25–28], there might be a clinical preference from the current point of view to use such products. Nevertheless, the use of calcium hydroxide results in similar clinical success rates. In addition, the findings from our data should not be overstated due to the observational character of this investigation and the low case numbers in some categories and must be verified in future clinical trials.

Another relevant question for clinicians regards the possible time point when an endodontic failure may occur. Here, 64.3 to 89.5% of all documented endodontic events—loss of pulp vitality—occurred within the first year after dental

Table 3 Results from the logistic regression analysis which analyses potential associations between uncomplicated and complicated crown fractures and injury or treatment relevant covariables

	Loss of pulp vitality		Loss of restoration	
	Hazard ratio (95% CI)	*p* value	Hazard ratio (95% CI)	*p* value
Uncomplicated crown fractures				
Age	0.99 (0.98–1.02)	0.729	1.00 (0.99–1.02)	0.558
Gender				
Male	1.00		1.00	
Female	1.50 (0.81-2.76)	0.209	0.95 (0.54-1.69)	0.864
Periodontal diagnosis				
No luxation	1.00		1.00	
Luxation	*4.61 (2.47–8.61)*	*< 0.001*	*0.30 (0.10–0.98)*	*0.046*
Pulp protection				
None	1.00		1.00	
Indirect pulp capping	1.79 (0.74-4.35)	0.196	1.36 (0.57-3.22)	0.483
Restorative treatment				
Reattachment	1.00		1.00	
Direct restoration	2.29 (0.80-6.51)	0.121	*0.35 (0.19–0.62)*	*0.000*
Complicated crown fractures				
Age	*1.10 (1.03–1.17)*	*0.007*	1.01 (0.96-1.07)	0.655
Gender				
Male	1.00		1.00	
Female	2.46 (0.85-7.08)	0.096	1.12 (0.47-2.64)	0.804
Periodontal diagnosis				
No luxation	1.00		1.00	
Luxation	0.97 (0.27-3.52)	0.964	1.10 (0.40-2.97)	0.859
Pulp treatment				
Root canal treatment	–	–	1.00	
Direct pulp capping ($Ca(OH)_2$)	1.00		0.75 (0.22-2.61)	0.654
Direct pulp capping (MTA)	1.72 (0.47-6.25)	0.413	0.99 (0.28-3.53)	0.992
Pulpotomy ($Ca(OH)_2$)	2.43 (0.35-16.94)	0.368	0.50 (0.08-3.18)	0.463
Pulpotomy (MTA)	0.48 (0.05-4.41)	0.517	0.55 (0.11-2.72)	0.459
Restorative treatment				
Reattachment	1.00		1.00	
Direct restoration	1.42 (0.48-4.21)	0.526	*0.37 (0.14–0.93)*	*0.034*

Italic numbers indicate a significant association

trauma (Table 4). At least 78.6% of all endodontic events were diagnosed 2 years after the accident (Table 4), which is further illustrated in the Kaplan-Meier curves (Figs. 1 and 2). Based on this finding, a quarterly follow-up of crown fractures over 2 years seems to be indicated. Recall intervals may be prolonged 2 years after the trauma, as only few cases of complications appeared thereafter.

Another frequently diagnosed complication was the loss of restoration. Interestingly, the proportions were higher in the group with complicated crown fractures than in the group with uncomplicated crown fractures (Tables 1 and 2; Figs. 1 and 2). These numbers were explained by the fact that complicated crown fractures are frequently linked to a more severe hard tissue defect, which requires more extensive restoration than uncomplicated crown fractures. In contrast, restorative treatment in teeth with uncomplicated crown fractures exhibited the highest survival probability (Tables 1 and 2). Another clinically relevant finding from this report is that direct restorations performed better than reattachment of tooth fragments. This finding needs to be carefully interpreted because the use of crown fragments should be considered the restorative method of choice due to its minimal invasiveness and natural aesthetics [29, 30]. In contrast to this finding, the use of direct composite restorations is linked to higher survival rates because of the probability of bevelling the restoration margins and enlarging adhesions in the enamel. With respect to these important clinical variables, the documented survival rates (Table 3) should not be misinterpreted to favour direct restorations in primary dental trauma care. Finally, it can be concluded from our data in comparison to existing information

Table 4 Overview of the intervals before complications occurred with respect to the loss of vitality or loss of restoration

Diagnosis	Time (years)	Loss of vitality			Loss of restoration		
		N	%	Cum. %	*N*	%	Cum. %
Uncomplicated crown fracture without luxation (*N* = 419)	< 0.5	14	53.8	53.8	26	51.0	51.0
	0.5–1.0	5	19.2	73.1	5	9.8	60.8
	1.1–1.5	2	7.7	80.8	8	15.7	76.5
	1.6–2.0	1	3.8	84.6	3	5.9	82.4
	> 2.0	4	15.4	100.0	9	17.6	100.0
	∑	26	100.0	100.0	51	100.0	100.0
Uncomplicated crown fracture with luxation (*N* = 70)	< 0.5	16	84.2	84.2	2	66.7	66.7
	0.5–1.0	1	5.3	89.5	–	–	–
	1.1–1.5	–	–	–	–	–	–
	1.6–2.0	–	–	–	–	–	–
	> 2.0	2	10.5	100.0	1	33.3	100.0
	∑	19	100.0	100.0	3	100.0	100.0
Complicated crown fracture without luxation (*N* = 101)	< 0.5	9	64.3	64.3	9	47.4	47.4
	0.5–1.0	–	–	–	5	26.3	73.7
	1.1–1.5	2	14.3	78.6	2	10.5	84.2
	1.6–2.0	–	–	–	2	10.5	94.7
	> 2.0	3	21.4	100.0	1	5.3	100.0
	∑	14	100.0	100.0	19	100.0	100.0
Complicated crown fracture with luxation (*N* = 26)	< 0.5	5	71.4	71.4	3	50.0	50.0
	0.5–1.0	1	14.3	85.7	1	16.7	66.7
	1.1–1.5	1	14.3	100.0	1	16.7	83.3
	1.6–2.0	–	–	–	–	–	–
	> 2.0	–	–	–	1	16.7	100.0
	∑	7	100.0	100.0	6	100.0	100.0

from the literature [31–33] that restorations placed in the present study were associated with high survival rates. When reporting the longevity of restorations, the clinician must also know the time intervals in which losses of restoration may occur. Within the first years after the primary restoration was placed, 60.8 to 73.7% of all failures were diagnosed. These numbers increased to 66.7 to 94.7% of failed restorations after 2 years (Table 4). Even in the case of a possible loss of restoration, the previously mentioned recommendation to monitor traumatized teeth closely over 2 years needs to be repeated.

A worst-case scenario, which never occurred during the observation period, was the indication for extraction of any permanent teeth. This finding indicates a primarily successful dental management of crown fractures, which was also documented in other studies [8, 23, 34]. Nevertheless, seven teeth with a documented complicated crown fracture were removed by the dentist who was responsible for emergency care. This decision was part of the initial treatment and was not the result of complications during the observation period after conservative therapy. Here, we presumed that these teeth experienced multiple damages, and the prognosis was therefore probably assessed as poor. All patients with extractions had been referred for further treatment by private or other external (dental) healthcare providers. When considering the proportion of patients who were not treated at the Department of Conservative Dentistry and Periodontology, this retrospective, practice-based analysis also included patients who were probably not always treated according to the latest treatment protocols; thus, heterogeneity in the treatment protocols used by dentists in dental practices and dentists at the Department of Conservative Dentistry and Periodontology might exist.

The strength of the present retrospective, longitudinal case-control study is the large sample size and detailed analysis of data, including the presence or absence of a luxation injury. Furthermore, all included patients were treated after the turn of the millennium, indicating that treatment decisions were made based on recently published clinical guidelines [16–18]. Based on the results from the survival analyses (Figs. 1 and 2), valuable information about the prognosis of (un)complicated crown fractures was provided.

Some limitations of this investigation are related to the study design. In general, a prospective study design would

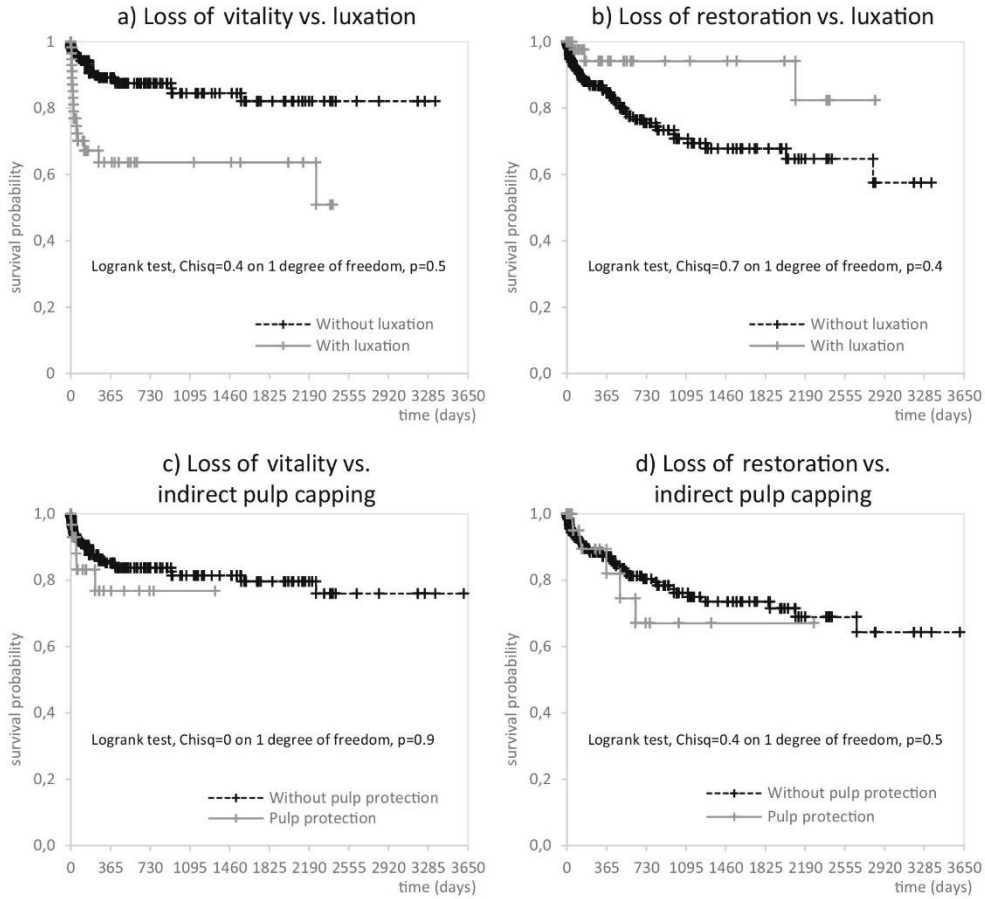

Fig. 1 The Kaplan-Meier curves for uncomplicated crown fractures illustrate the pulpal survival probability and longevity of direct restorations in relation to additional luxation injuries (**a**, **b**) and the use of indirect pulp capping (**c**, **d**)

ensure more reliable data but is difficult to achieve since the participation of the patient must already be obtained in an emergency situation, which is questionable from an ethical perspective [20]. Therefore, retrospective analyses are frequently used in dental traumatology [3, 4, 23, 25, 35–37] but have several limitations. Most importantly, all information was only collected from patient records, radiographs, photographs, doctor's letters or trauma documentation sheets. Thus, information was missing for some patients, which was not compensated from other sources of information. Furthermore, the present samples of patients with dental trauma might have been influenced by the different levels of clinical experience and skills of dental practitioners at the primary dental care facility. In this study, approximately 20 doctors treated patients in the Department of Conservative Dentistry and Periodontology at different frequencies. Therefore, divergent diagnostic and treatment decisions might have occurred, which may limit the informational value of the present report. In addition to the heterogeneity of practitioners, the changes in treatment policies [16–18] over the years must also be considered. When considering this study, patients receiving non-IADT guideline-compliant treatments may also be present in this pool of patients/data. Nearly 40% of the patients initially received treatment in the Department of Conservative Dentistry and Periodontology, and the remaining proportion was referred to the department after emergency treatment. Therefore, we were sometimes unable to collect detailed information about the IADT guideline-conforming initial treatments for the latter group.

A further limitation of practice-based, retrospective studies is that the study design did not include strict recall intervals after the initial treatment visit. While many patients adhered to the recommendations of dental team at the University Hospital, several other patients asked other professionals to

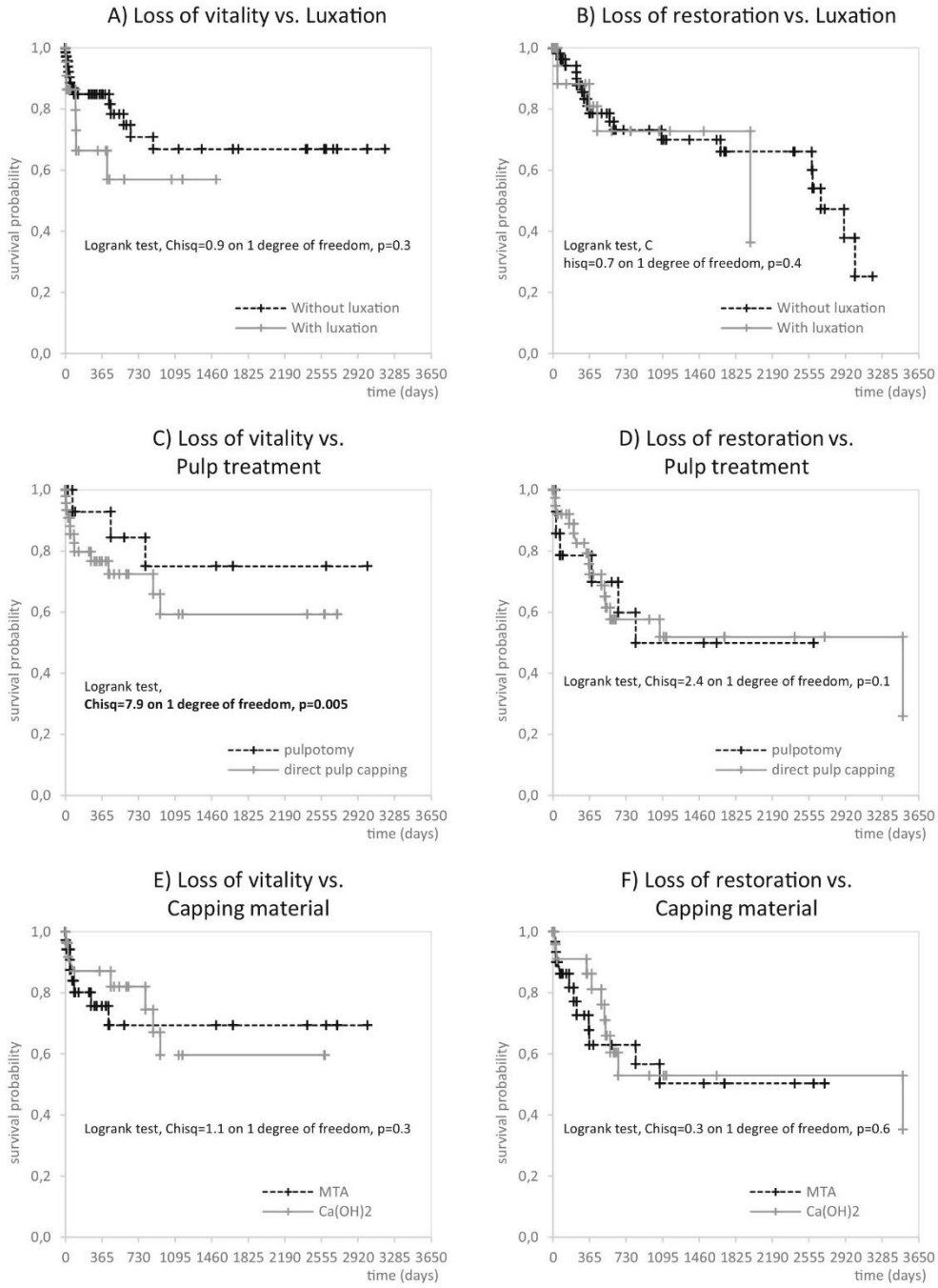

Fig. 2 The Kaplan-Meier curves for complicated crown fractures illustrate the pulpal survival probability and longevity of direct restorations in relation to additional luxation injuries (**a**, **b**), the indicated pulp treatment (**c**, **d**) and used pulp capping material (**e**, **f**)

perform the monitoring after the dental trauma and were, therefore, lost to follow-up in the present study. Consequently, the number of patients with long follow-up times decreased with an increasing observation time.

Conclusions

Regarding the overall number of traumatic events in the permanent dentition, crown fractures are a frequent injury that must be appropriately addressed by the general dental practitioner. When considering that most of the contemporarily recommended treatment protocols by the IADT were applied to the included patients and the high survival rates, it can be concluded that these clinical procedures are linked with successful treatment outcomes in the majority of patients. In addition, the following conclusions can be drawn: (1) the loss of pulp vitality should be considered a potential complication, which might be more likely to occur in cases of an additional luxation injury; (2) no statistically significant superiority of MTA or calcium hydroxide as pulp capping material in cases of complicated crown fracture was detected; (3) restoration failure was more frequently detected in reattached crown fragments; and (4) based on the registered survival rates and the fact that most complications occurred within the first 2 years after dental trauma, close clinical monitoring intervals over the first 24 months after the initial trauma are justified.

Acknowledgements Open Access funding provided by Projekt DEAL.

Funding information This research was funded by the institution. The authors declare no potential conflicts of interest with respect to the authorship and publication of this article, including financial interests and the provision of study materials by the manufacturer for free or at a discount.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was obtained from the Human Ethics Committee of the Medical Faculty of the Ludwig-Maximilians-University, Munich (Project no. 670-16).

Informed consent Informed consent was obtained from all participating children and their legal guardians.

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Veröffentlichung II

Received: 17 February 2020 | Revised: 23 September 2020 | Accepted: 25 September 2020

DOI: 10.1111/edt.12613

ORIGINAL ARTICLE

Dental Traumatology WILEY

Survival analysis of adhesive reattachments in permanent teeth with crown fractures after dental trauma

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Abstract

Background/Aim: When patients have saved tooth fragments in case of crown fractures, reattachment is considered as the treatment of choice. With respect to the need to provide clinical outcome data regarding adhesively reattached fragments, the aim of this practice-based clinical study was to evaluate the survival of reattached fragments after crown fractures in permanent teeth.

Materials and Methods: Records from patients treated at Ludwig-Maximilians-University between 2004 and 2017 were analyzed to collect clinical and radiographic data regarding the management of fractured teeth that were treated with an adhesive reattachment. The study population consisted of 109 patients comprising 135 reattached fragments divided into uncomplicated (N = 84/135) and complicated (N = 51/135) crown fractures. The Kaplan-Meier Survival estimator was used to estimate the survival probability of primary reattachments after uncomplicated and complicated crown fractures.

Results: Overall, 77.4% (N = 65/84) and 66.6% (N = 34/51) of the primarily applied reattachments in uncomplicated fractured teeth and complicated fractured teeth, respectively, survived over the period of observation. The survival rate for adhesive reattachment in all teeth was 84.4% (N = 114/135) after 608.2 days (±983.1 days). The data further suggest that in the case of a detachment, repeated reattachment might be a valuable restoration strategy.

Conclusions: Adhesive reattachment is a good first-choice treatment option in cases of crown fractures when the fractured fragment has been saved.

KEYWORDS

adhesive reattachment, complicated crown fracture, dental trauma, longevity, survival probability, uncomplicated crown fracture

1 | INTRODUCTION

There is a high prevalence of dental trauma, especially in the first two decades of life.[1-4] Due to their exposed position in the dental arch, the maxillary incisors are particularly frequently injured. This problem requires functional, aesthetic, and efficient restoration, which could be achieved primarily with direct, adhesively bonded composite restorations or, in the case that the fractured fragment is present/saved, with an adhesive reattachment of the fragment as recommended by the International Association of Dental

Ethical Approval project number: Project no. 670-16

Traumatology (IADT) guidelines.[5-8] The latter technique is a good first choice in dental practice due to the possibility of restoring the individual crown form (shape, color, translucence, and surface texture), aesthetics, and functionality in the shortest amount of time (Figure 1). Furthermore, this treatment approach is arguably minimally invasive, simple to perform and, therefore, an efficient restoration technique.[9-12]

In addition, reattachments are associated with a low or equal survival probability in comparison with that of direct composite restorations.[9,13,14] Unfortunately, the number of laboratory and clinical studies is small.[9,10,14-16] Most importantly, clinical data and experience originate from older reports or case series only.[17-24] As such, there is a need to provide more fundamental data about the clinical outcome and prognosis of adhesively reattached fragments. Therefore, the aim of this study was to evaluate the reattachment of permanent teeth fragments performed in the Department of Conservative Dentistry and Periodontology due to dental trauma between January 2004 and June 2017.

2 | MATERIALS AND METHODS

This retrospective study was conducted in accordance with the Declaration of Helsinki. Ethical approval of the Human Ethics Committee of the Medical Faculty of the Ludwig-Maximilians-University, Munich was obtained.

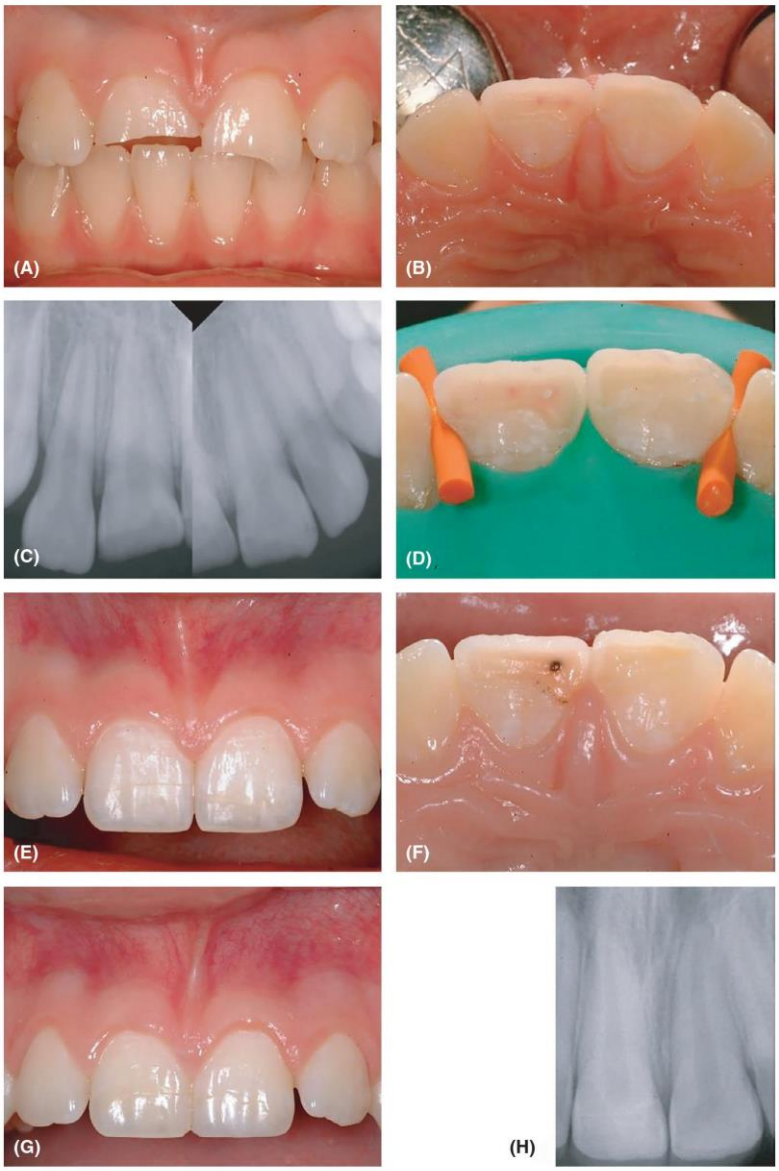

FIGURE 1 An example of a patient with complicated (11) and uncomplicated fractured permanent incisors (21) after dental trauma (A-C). Following pulp capping with a bioactive endodontic cement on tooth 11 (D), both fragments were adhesively reattached (E). Three months after primary reattachment, both fragments detached as a result of another incident of trauma (F). The saved fragment of tooth 11 was reattached, and tooth 21 needed a direct restoration due to loss of the fragment. Two years after initial treatment, both incisors are well restored (G). In addition, there were no signs of pulp pathosis (G) and the periapical radiograph showed regular root development for both incisors (H)

The study included patients affected by trauma who sought dental treatment at the Department of Conservative Dentistry at the Ludwig-Maximilians-University of Munich between January 2004 and June 2017. Patients with caries-related dental hard tissue loss or teeth with developmental disorders, hypomineralization, or hypoplasia were excluded from the study. Additionally, cases with non-traumatic tooth loss or luxation caused by periodontal diseases were not included.

The procedures at the Department of Conservative Dentistry and Periodontology can be described as follows. Before treatment, each patient was clinically and radiographically examined. In the diagnostic evaluation, each traumatized tooth was classified on the basis of the well-accepted criteria by Andreasen and Andreasen.[25] Furthermore, a consistent examination of the dental hard tissues, pulp, periodontium, alveolar bone, and gingiva was performed during the initial and recall visits at the Department of Conservative Dentistry and Periodontology.[26]

When the patients had saved their fractured fragments, reattachment was considered irrespective of the defect size and pulp exposure. Cases with direct pulp exposure (complicated crown fracture) needed appropriate endodontic measures before the restoration of the tooth was performed. In brief, pulps of complicated crown fractures were capped with a bioactive cement, for example, mineral trioxide aggregate (ProRoot MTA, Dentsply Sirona, York, PA, USA or Medcem MTA, Medcem GmbH, Wien, Austria) or an aqueous calcium hydroxide suspension.

In such cases, it was important to rehydrate the fractured fragment prior to adhesive reattachment to prevent inappropriate color change and aesthetics, and to increase the fracture resistance of the reattached fragment.[10] To compensate for dehydration, each affected fragment was stored for ~30 minutes in a pressure polymerization device (Heraeus Palamat® elite, Heraeus Holding GmbH, Hanau, Germany) with a pressure of ~2.0 (atmospheres) bar at room temperature.[10,27] If the rehydration remained unsuccessful, as shown by the inadequate shade adaptation and chalky surface of the fragment, the procedure was repeated. During the fitting, the marginal fit was checked, and a decision was made regarding whether the fragment needed to be complemented by a direct restoration.

In general, all reattachments were performed without enamel chamfering and/or central hollowing of the fragment.[28,29] Following the total etch technique, the tooth and the fragment were etched with a 37% phosphoric acid etching gel (Total Etch, Ivoclar Vivadent GmbH, Schaan, Liechtenstein) for ~20 seconds, and the adhesive (Syntac Classic, Ivoclar Vivadent GmbH, Schaan, Liechtenstein) was applied according to the manufacturer's instructions and spread with compressed air.[15] To establish optimal bond strength and to compensate for missing parts of the enamel, a thin layer of flowable composite (Tetric Flow, Ivoclar Vivadent GmbH, Schaan, Liechtenstein) was applied before repositioning the fragment. After correct fragment positioning, light polymerization of the adhesive and flowable composite was initiated. Finally, any excess material was removed. Following emergency treatment, all patients were offered regular recall visits to monitor the traumatized teeth.

In case of a subsequent fragment detachment, a further reattachment procedure was considered, and the treatment protocol was carried out exactly as in the first reattachment.

In order to obtain all relevant information about the treated cases, two of the authors (RB and DDM) analyzed the paper-based and, from 2012 onwards, electronic dental records. Information was entered in a customized database (EpiData Software, version: V4.0.2.101, EpiData Association, Odense, Denmark). The data collection included the following: first, the patients' characteristics (eg, age and gender); second, relevant information about the traumatized teeth and information about the accident (eg, diagnosis and previous dental trauma); and third, details of the corresponding treatment and recall. If the documentation was inadequate or if the minimum required information could not be taken from the patient's records, the patient was excluded. The data set was transferred for further analysis and evaluation via a.csv file in Excel (Microsoft Office 365 Excel, version 1804, Redmond, WA, USA).

Microsoft Excel and SPSS (version 21.0.1, SPSS Inc, Armonk, NY, USA) were used to perform the descriptive and explorative data analysis. For analysis of the lifetime data, Kaplan-Meier curves were computed.[30] For the survival analysis of the reattachments and the reattachments complemented by an additional direct restoration, injuries were grouped into uncomplicated and complicated crown fractures. The loss of reattachment was documented when the fragment had detached, and the fragment was adhesively reattached, or the defect was restored by a direct restoration. Pulp necrosis was recorded when a tooth did not respond to pulp sensibility tests—with or without the presence of periapical inflammation—and the tooth received a root canal treatment.

3 | RESULTS

A total of 898 patients (529 males/ 369 females; mean age of 16.9 years; range 0-86 years) with 1756 traumatized teeth (1344 permanent teeth/ 412 primary teeth; mean of 2.0 injured teeth per accident) were included. Crown fractures were the most frequently documented injury, with a total of 489 cases of uncomplicated crown fractures and 127 cases of complicated crown fractures. All cases were selected where the fractured fragment was reattached to the tooth with an adhesive technique. A total of 109 patients (70 males/39 females; mean age of 15.7 years; range 6-64 years) with 135 reattached fragments (84 teeth with uncomplicated crown fractures (N = 84/489; 17.2%)/ 51 teeth with complicated crown fractures (N = 51/127; 40.2%); mean of 1.2 reattached teeth per accident) were identified.

The maxillary central incisors were the most frequent type of tooth in which reattachment was performed (N = 119/135, 88.2%), followed by the maxillary lateral incisors (N = 13/135, 9.6%). Maxillary premolar teeth (N = 2/135, 1.5%) and mandibular lateral incisors (N = 1/135, 0.7%) were less frequently reattached. A total of 13.3% (N = 18/135) of the reattachments were done with an additional restoration because parts of the fragment were lost/missing.

The mean observation time was 608.2 days (range 0-4837 days, standard deviation 983.1 days). The mean time interval until the fragment detached was 240.8 days (standard deviation 274.2 days).

Table 1 shows the following observations: 77.4% (N = 65/84) and 66.6% (N = 34/51) of primarily applied reattachments in uncomplicated and complicated fractured teeth, respectively, survived over the whole period of observation. The reattached fragments dislodged in 22.6% of uncomplicated crown fractures (N = 19/84) and 33.3% of complicated crown fractures (N = 17/51).

Detachments were observed mostly within the first year after primary treatment (Table 2). The time flow of all reattachments is shown in Figure 2. There were 52.8% (N = 19/36) of the first detachments that were treated with a second reattachment procedure. The second reattachments had a success rate of 68.4% (N = 13/19). In the case of a second detachment, 33.3% (N = 2/6) were treated with a third reattachment and these had a success rate of 100% (N = 2/2). When all teeth were considered, 84.4% were treated successfully using an adhesive reattachment of the fractured fragments (N = 114/135). The Kaplan-Meier curves that estimate survival from the lifetime data are shown in Figure 3.

Regarding the pulp status after reattachment, in 95.2% (N = 80/84) of teeth with uncomplicated crown fractures, the pulp remained clinically normal within the observation period. Pulp necrosis and infection occurred in 4.8% (N = 4/84) of cases. In teeth with reattachment after a complicated crown fracture, the pulp survived in 82.4% (N = 42/51) of cases and pulp necrosis and infection occurred in 17.6% (N = 9/51) of cases.

4 | DISCUSSION

This retrospective study provides long-term data about the outcome and prognosis of fragment reattachments to fractured permanent teeth. Given the sample size of 135 teeth and the mean observation time of nearly two years, this report provides medium-term clinical information in relation to previously published case series.[18-21,23,24]

The main finding from this study is that 84.4% of all teeth with saved fragments were successfully restored with reattachment (Figure 2). Nevertheless, detachments can occur in some cases but can mostly be re-treated successfully by a further reattachment procedure.

When considering the pulp status as an additional outcome, it can be concluded that only a small number of cases develop pulp necrosis. This proportion was slightly higher in cases of complicated crown fractures compared with uncomplicated crown fractures. This finding is in line with the available literature.[3,31,32] It is possible or even most likely that the trauma event itself led to pulp necrosis. Nevertheless, any treatment procedure may also affect the pulp status. With respect to the study design, reasons for pulp necrosis could not be distinguished.

Reattachments survived more frequently in teeth with uncomplicated crown fractures than in teeth with complicated crown

TABLE 1 Overview of the success rates, complication rates of reattachments with one loss and multiple losses in teeth with uncomplicated crown fractures and complicated crown fractures

		Success		1st Detachment (N = 36)						2nd Detachment (N = 6)					
				2nd Reattachment						3rd Reattachment					
				Success		2nd Detachment		Direct composite restoration		Success		3rd Detachment		Direct composite restoration	
Diagnosis	Primary treatment	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Uncomplicated crown fracture (N = 84)	Reattachment (N = 72)	55	76.4	4	5.5	3	4.2	10	13.9	-	-	-	-	3	4.2
	Reattachment &restoration (N = 12)	10	83.3	-	-	-	-	2	16.7	-	-	-	-	-	-
Complicated crown fracture (N = 51)	Reattachment (N = 45)	30	66.7	8	17.7	2	4.4	5	11.1	1	2.2	-	-	1	2.2
	Reattachment & restoration (N = 6)	4	66.7	1	16.7	1	16.7	-	-	1	16.7	-	-	-	-
	Total (N = 135)	99	73.3	13	9.6	6*	4.5*	17	12.6	2	1.5	-	-	4	3.0

*Cases in this category have to be counted in the category "2nd detachment."

TABLE 2 Overview of the periods until loss of reattachment occurred, with respect to single loss of reattachment or multiple losses of reattachment

Diagnosis	Time (years)	1st Detachment (N = 36) N	%	Cum. %	2nd Detachment (N = 6) N	%	Cum. %
Uncomplicated crown fracture (N = 84)	<0.5	11	57.9	57.9	3	100.0	100.0
	0.5-1.0	3	15.8	73.7	-	-	-
	1.1-1.5	2	10.5	84.2	-	-	-
	1.6-2.0	1	5.3	89.5	-	-	-
	>2.0	2	10.5	100.0	-	-	-
	∑	19	100.0	100.0	3	100.0	100.0
Complicated crown fracture (N = 51)	<0.5	9	52.9	52.9	2	66.7	66.7
	0.5-1.0	5	29.4	82.4	1	33.3	100.0
	1.1-1.5	2	11.8	94.1	-	-	-
	1.6-2.0	1	5.9	100.0	-	-	-
	>2.0	-	-	-	-	-	-
	∑	17	100.0	100.0	3	100.0	100.0

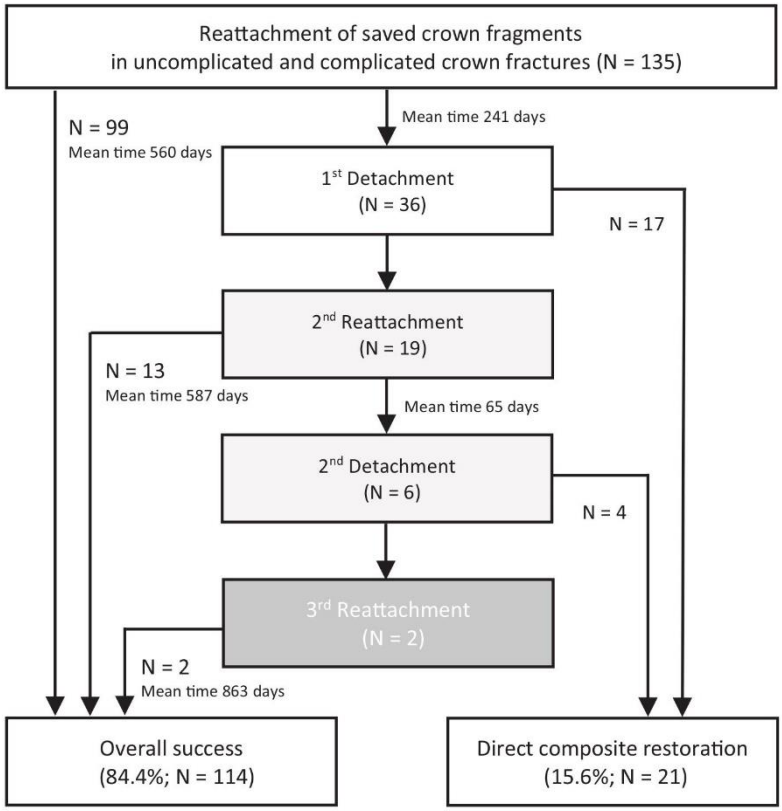

FIGURE 2 Illustration of the success or detachment of primary reattachments and treatment options after loss of the primary reattachment

fractures (Table 1). A possible explanation for this finding is that more severely fractured teeth typically result in larger fragments as in the case of complicated crown fractures and this resulted in higher rate of detachment (Table 1). Another possible explanation for this in complicated crown fractures is the relatively longer lever arm, which might negatively affect the adhesively reattached fragment. Furthermore, the need for additional direct restoration of uncomplicated crown fractures increased the probability of success in these teeth (Table 1). These results were in accordance with earlier published data by Brambilla and Cavallè,[33] who proposed that in case of

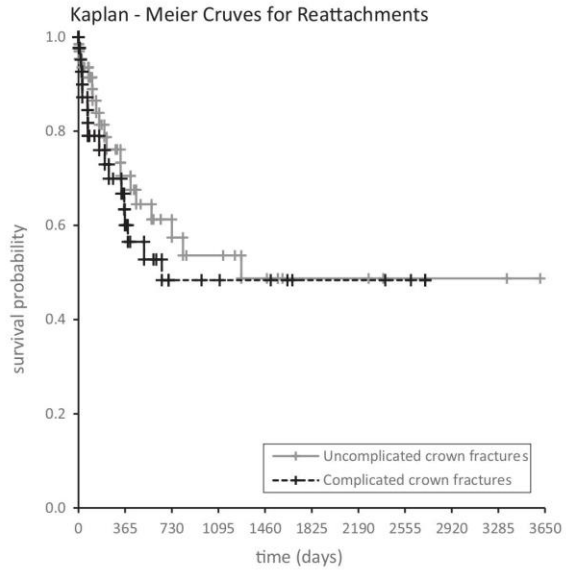

FIGURE 3 Kaplan-Meier curves illustrating the survival probability of primary reattachments after uncomplicated and complicated crown fractures

a perfect fit, no preparation should be performed and that in case of discrepancies, additional efforts should be made to re-establish function and aesthetics.

This study is similar to previously published reports which showed that a distinct proportion of reattached fragments will be lost.[9,14,16,17] Such events mostly occurred within the first year after the accident in the present sample (Table 2). Interestingly, most of the fragments were re-reattached again with an adequate high survival rate (Figure 2). Nevertheless, some cases needed to be restored with a conventional composite restoration because the fragment was lost or reattachment was impossible (Table 1 and Figure 2). This requires that special focus be given to monitoring, especially in the first year after reattachment.

The current data support the recommendation to consider the reattachment of fractured fragments as the method of first choice in clinical practice. Therefore, patients and/or their accompanying persons who seek emergency treatment after dental trauma should be advised to search for tooth fragments at the accident site. It is also recommended to examine soft tissue injuries for possible scattered fragments prior to restorative dental treatment. Both options should be taken into account before placing a direct composite restoration and when the tooth fragments are not present.

As mentioned by Madhubala et al,[10] despite the recommendation for reattachment, the IADT guidelines unfortunately do not provide any information or protocol for rewetting fractured fragments. However, Madhubala et al[10] were able to demonstrate the importance of rewetting to increase fracture resistance after reattachment. Poubel et al[34] demonstrated that rehydration in the case of dehydrated fragments is important to increase the bond strength. In contrast, Yilmaz et al[16] could not detect any significant difference in the survival of reattachments after dry or moist storage.

One of the strengths of this study is the sample size of 135 teeth. Thus, the study contrasts with other comparable studies or case reports which had lower numbers of cases.[9,14,16] When contemplating potential limitations of this practice-based study, one must mention that this investigation collected clinical data retrospectively without an additional, study-intended clinical examination of the patients. Consequently, this study design is less reliable than a prospectively designed clinical trial with respect to inclusion and exclusion criteria, data collection or recall intervals. Furthermore, the use of clinical procedures might differ between operators and potential failures or side effects might be reported to other professionals and not the study group. All of these aspects may limit the ability to generalize the results. Unfortunately, it was not possible to consider the potential reasons or indicators for fragment loss (eg, steps of the clinical workflow, mal-adaptation or insufficient positioning of the fragment, traumatic occlusion, premature contacts, or less cooperative behavior of the child).

5 | CONCLUSION

This practice-based, retrospective study investigated the survival of adhesively reattached tooth fragments after dental trauma and showed that 84.4% of all teeth were successfully restored. The data suggest that in the case of a detachment, another reattachment might be a valuable restoration strategy. When the overall high success rates, clinical advantages, and potential limitations are considered, adhesive reattachment should be the first-choice treatment in cases of crown fractures when the fragment has been retrieved or saved.

ACKNOWLEDGEMENTS

This research was funded by the institution, with no conflicts of interest, and all authors provided their services on a purely scientific basis.

CONFLICT OF INTEREST

The authors state explicitly that there are no conflicts of interest.

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How to cite this article: Bissinger R, David Müller D, Hickel R, Kühnisch J. Survival analysis of adhesive reattachments in permanent teeth with crown fractures after dental trauma. *Dental Traumatology*. 2021;37:208–214. https://doi.org/10.1111/edt.12613

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Danksagung

An dieser Stelle möchte ich meinen besonderen Dank nachstehenden Personen aussprechen, die mich während der Anfertigung meiner Doktorarbeit unterstützt haben.

Mein besonderer Dank gilt zunächst Herrn Prof. Dr. Jan Kühnisch, meinem Doktorvater für die Überlassung des Themas, seiner Betreuung dieser Arbeit sowie seine freundliche und fachliche Hilfe. Ich möchte mich für die Unterstützung und Motivation während des gesamten Promotionszeitraumes bedanken.

Des Weiteren möchte ich mich bei Herrn Vinay Pitchika für die Hilfe bei der Erstellung der Datenbank bedanken. Daneben soll hier Herrn Thomas Obermeier für die Unterstützung bei IT-Problemen gedankt werden.

Mein Dank gilt auch den Mitarbeiterinnen der Anmeldung/Ambulanz sowie des Sekretariats die bei der Bereitstellung und Auffindung der Patientenakten zur Hilfe standen.

Nicht zuletzt möchte ich mich auch bei meinen Eltern bedanken, die mir dieses Studium ermöglicht haben. Auch Helma und Mayer, meiner Schwester Beatrice und meinen Freunden möchte ich danken die mit motivierenden und verständnisvollen Worten an meiner Seite waren.