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Dental Implants and Trauma

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Abstract

Implant dentistry treatment target to avoid any kind of edentulous state including tooth loss due to trauma. In the literature there are numerous case reports and few clinical studies documenting treatment options of post-trauma patients by dental implants. Principally there are some limitations of dental implant application related to the age and available bone volume of patients. Implant candidate should complete bone growth as the metallic implants do not follow bony development phases. Most often traumatic dental injuries occur in childhood and implant treatment should postponed. In this aspect the major problem associated with dental implant placement is the lack of adequate bone volumes at the future time of surgery as such cases receives traumatic dental injury in the early years and disuse atrophy occurs during waiting period. Future trends and strategies in dental traumatology in general and with special attention to dental implant applications are based on the education of population in terms of emergency treatments and urgent transport of patients to the clinics.

Keywords: dental implant, trauma, implant placement, dental lasers, erbium laser, traumatic injuries, iatrogenic factors

1. Introduction

Dental implant applications are wide spreading globally and in last three decades it is the major attraction field for both clinicians and patients. Implant dentistry treatments target to avoid any kind of edentulous state including tooth loss due to trauma. Tooth loss after trauma could be related to traumatic dental injuries depending from violence, falls, traffic accidents, gunshots or to late consequences of trauma such as recurrent endodontic lesions, vertical root fractures, external or internal root resorptions and ankylosis which bring teeth to untreatable condition. Trauma-related tooth loss most often involve anterior maxillary teeth and generally is rehabilitated as single tooth implant replacement or several teeth are affected and rehabilitation is made as a solution of partially edentulous case but being in the anterior region with the rules of single-tooth replacement to preserve esthetics. Patient age constitute another aspect of post-trauma cases where accidents mainly happen in childhood period which is not favorable for dental implant applications due to incomplete bony growth. For the patients in development stage there should be followed special attention for future dental implant rehabilitation. Thus, care must be taken to find suitable treatment solutions in order to provide interim prosthetic treatment, to follow normal bone growth, avoid hard tissue atrophy and preserve alveolar bony dimensions for upcoming implant surgery in the late adolescent age. In the present chapter post-trauma applications of dental implants are discussed and possible treatment strategies are evaluated.

2. Etiology, prevalence of traumatic dental injuries and implant dentistry

Traumatic dental injuries (TDIs) have different frequencies worldwide, but always low prevalence among communities [1–6]. Etiologic factors of TDIs are various from country to country and with age groups [7]. Globally the most common etiology of TDI in men is violence. For women there are three most common injury factors: violence, falls and traffic injuries [6, 8–10]. Ballistic injuries (gunshots) form a severe type of traumatic maxillofacial injury [11, 12] and can be classified in between the etiologic factors of TDIs. TDI studies most often cover children and adolescents. There are few studies involving adults [1, 6, 13, 14]. Studies show that the TDIs affect mainly anterior maxilla and especially central incisors [3, 8, 15–17]. Generally teeth involved by TDIs are lost in the long run and subsequently this anatomic lack may result in significant esthetic and functional problems [6].

The consensus statements of International Association of Dental Traumatology (IADT) propose to delineate approaches for the immediate or urgent care for management of primary and permanent teeth injuries [9, 10, 18]. The emergency treatment after TDIs is highly important for the future management of dental structures [15, 16]. Although attempts is to preserve natural dentition and despite best efforts at retaining and maintaining trauma-compromised teeth, studies show that in the long run affected teeth are loose and replaced by dental implants [19]. Studies and case reports are shown that implant placement after TDIs is a suitable treatment of choice [20–22].

In the epidemiological study, Ugolini et al. [1] determined the prevalence, types, and characteristics of occupational (work-related) TDIs in a large working community where among 212 traumatized teeth, upper incisors took the first place with 67.5%, lower incisors showed 17.5% incidence, upper canines were only 3.3%, lower canines with 1.9% were less than uppers, and bicuspids and molars had 9.9% prevalence. In conclusion occupational TDIs exhibit a low prevalence and the most frequent dental injury type were fractures. Possible etiologic risk factors for occupational TDIs were mentioned to be the age, gender and existence of previous dental treatments.

Rozi et al. [15] studied complications of permanent teeth after TDIs in 50 children [age range 7–18 years (mean, 11 years); 32 (64%) males and 18 (36%) females]. According to the findings of this study, TDIs mostly involved the maxillary central incisors by 90% incidence. Uncomplicated enamel and dentin fracture without pulp exposure was the most common type of TDI with 62%. Only 50% of the cases showed luxation type injuries. The urgent and proper timing in treatment was underlined and it was considered to be the primary important strategy to increase the prognosis.

Zaleckiene et al. [2] reviewed etiology, prevalence and possible outcomes of dental trauma. TDIs prevalence was found to be different among countries. TDIs are more prevalent in permanent than in primary dentition. Treatment strategies are directed to eliminate undesired consequences, but TDIs in the young patient is often complicated and can continue during the rest of his/her life.

Atabek et al. [16] examined epidemiological and dental data from TDIs to primary and permanent teeth during the period from 2005 to 2010. The study included 120 girls (35.3%) and 220 boys (64.7%) with an average age of 9 years. The maxillary central incisors were most commonly affected teeth with a prevalence of 66.24%. The main cause of TDIs was found to be the falls by 70.1% incidence. In primary dentition highest percentage of injuries were subluxations with 36.4% rate. In permanent

dentition, uncomplicated crown fractures by 44.9% incidence were most frequent type of injury. In conclusion they stated that the prognosis of dental trauma cases varies depending on the time elapsed after the trauma before treatment started.

Zengin et al. [3] evaluated TDIs recorded using the World Health Organization classification modified by Andreasen et al. As the prevalence in a group of 5800 patient 255 had TDI (4.4%). TDIs were related mostly to the age group of 11–20 years. As gender distribution most affected were males (153 cases) and females got less injuries (102 cases). The main cause of traumatic injury was related to falls with 68.2% incidence, and generally trauma was taken place during outdoor activities by 56.1% prevalence. Upper central incisors took first place among the most frequently injured teeth with primary teeth injuries of 64.5% and permanent teeth injuries of 72.5%. Uncomplicated crown fracture was the most frequent type of TDI seen in both primary dentition with a percentage of 63% and permanent dentition with 47% incidence. In the population of the study, TDIs prevalence was considered to be low.

Unal et al. [17] through a retrospective study identified TDIs of 591 children (range 0–14 years, average age: 10.79 ± 2.06) referred to university hospital between years 2007 and 2012 in Sivas, Turkey. TDIs mostly occurred in the children of 12–14 years age group with 14% incidence. Dento-enamel fractures was the most common type of injury in primary teeth with 58% prevalence. Complicated crown fractures were most frequent type of TDI in permanent teeth with an incidence of 39%. The major etiologic factor of TDI was falls having 30% prevalence. The upper central incisors (71%) were the mostly affected teeth in both primary and permanent teeth. Only 63 children (11%) were referred to the clinic less than 30 minutes after trauma. The findings of this study showed that initial treatment after dental trauma should be performed immediately.

Kovacs et al. [4] in a retrospective study assessed the prevalence of TDIs in deciduous and permanent teeth among children and teenagers in Targu Mures city of Romania, between 2003 and 2011. The prevalence of TDIs was 24.5%. In the primary dentition the most frequent type of TDI was lateral incisor's luxation. In the permanent dentition, dento-enamel fractures without the exposure of the dental pulp were the most common type of TDI.

Hasan et al. [5] investigated a total of 500 of preschool children in Kuwait. The study reported TDIs etiologic factors, frequency, trauma type classification, injury localization and involved teeth numbers, treatment performed after injury. Among 500 children 56 subject got TDI involving 68 primary teeth with a prevalence of 11.2%. Fifty-three of 56 children got TDIs due to falls (94.6%). Upper primary central incisor was the most traumatized tooth with 55 units and 80.8% frequency. TDIs prevalence among such population was considered to be low.

Glendor [23] reviewed 12-years international literature regarding TDI to point the prevalence and incidence. TDIs were found to be a global phenomenon all over the world with variations in prevalence, etiologic factors, gender and localization of involved teeth. Across the world with slight differences from country to country, approximately 1/3 of preschool children got TDI in the primary dentition. Regarding TDI to the permanent dentition it could be concluded that although few variations among countries, about 1/4 of school children and almost 1/3 of adults received trauma.

According to Locker [13], 15.5% of the Canadians with age between 18 and 50 years old, living in the province of Ontario reported a history of injury to the mouth and teeth. The survey of this study involved 2001 adults who called by random digit dialing and answered to a questionnaire via telephone. Among the people who got TDI, 2/3 declared that injuries happened before the age of 18 years and 1/3 after adolescence.

Kaste et al. [14] reported findings of 7707 patients. According to Kaste's study, approximately one-quarter (24.9%) of the US population aged 6–50 years had at least one traumatized teeth.

Zerman and Cavalleri [6] examined 2798 patients having 6–21 years old age, with a follow-up period of 5-years in Verona, Italy. Among abovementioned population 178 were TDI cases, 131 males and 47 females, having 326 traumatized incisor teeth with a prevalence of 7.3%. Most frequent causes of injuries were falls and traffic accidents. A very large number of dental injuries occurred to children aged between 6 and 13 years. Most injuries involved two teeth. About 80% of the teeth were maxillary central incisors.

3. Dental implant treatment in post-traumatic dento-alveolar defects

In the literature there are numerous case reports and few clinical studies documenting treatment options of post-trauma patients by dental implants [24–29]. In those reports and studies cases underwent to trauma due to violence, falls, traffic injuries, gunshots which were later rehabilitated by use of dental implants are described in details. Treatment approaches reported are various as the cases exhibit different conditions related to the type of trauma, anatomy and age. Principally there are some limitations of dental implant application related to the age and available bone volume of patients. One of the main criteria for dental implant placement is the presence of complete bone growth as the metallic implants do not follow bony development phases [30–34]. Most often TDIs occur in childhood and implant treatment should postponed as mentioned [31]. Thus, the children who receives TDIs should wear removable or adhesive prosthesis until their skeleton mature. In this aspect the major problem associated with dental implant placement is the lack of adequate bone volumes at the future time of surgery as such cases receives TDI in the early years and disuse atrophy occurs during waiting period [21]. Maxillary central incisors area which is commonly affected zone by TDIs is most apparent site of the dentition and requires proper dimensions and proportions to establish esthetic and require complex treatment solutions such as bone grafting with autogenous or synthetic graft materials, guided bone regeneration applications; immediate, early or delayed implant placement methods (**Figures 1–7**).

Nicoli et al. [24] wrote records of a multidisciplinary treatment made in a gunshot injury case. Patient got severe anatomic defect in the mandible which was rehabilitated by use of an implant-supported fixed-removable dental prosthesis. In order to restore intermaxillary relation an immediately loaded provisional lower overdenture and upper removable prosthesis were delivered.

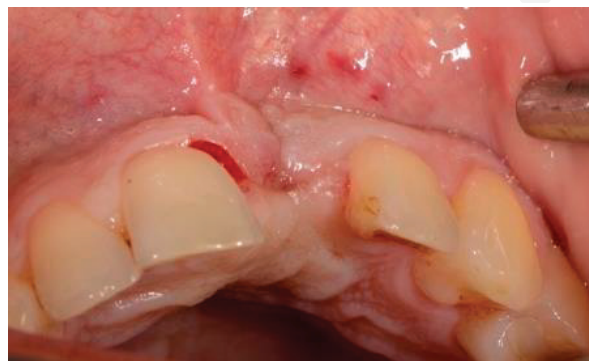


Figure 1. Traffic accident case: central incisor number 21 was lost due to a traffic incident trauma; bone volume was reduced in the buccal side and soft tissue was injured by a vertical laceration in the medial part of keratinized mucosa.

Following interim prosthesis installations, in order to increase the maxillary bone volume, nasal floor elevation and maxillary sinus lifting operations were performed. Subsequently definitive implant-supported fixed-removable prostheses were delivered in both arches to improve masticatory function and esthetics.

Fındık et al. [25] presented rehabilitation of a wide mandibular traumatic defect due to a work-related accident with iliac free flap, distraction osteogenesis, and dental implants. Distraction osteogenesis, free flap and dental implant placements were considered as an effective and esthetic treatment option for rehabilitation of post-trauma defects.

Balla et al. [26] described 5-year follow-up of surgical and prosthetic reconstruction of a gunshot injury using dental implants which was found to be

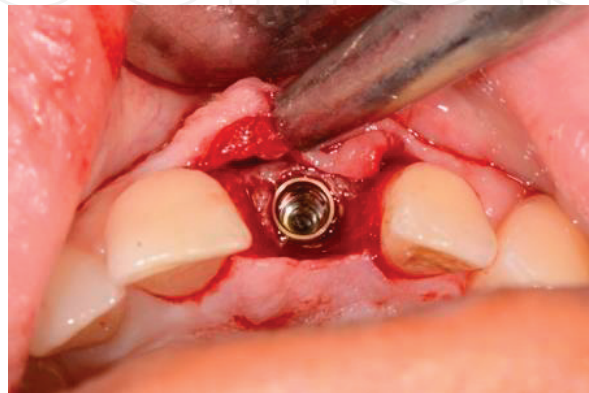


Figure 2.
Titanium/zirconia alloy dental implant (Bone Level SLA, Straumann AG, Swiss) was placed.

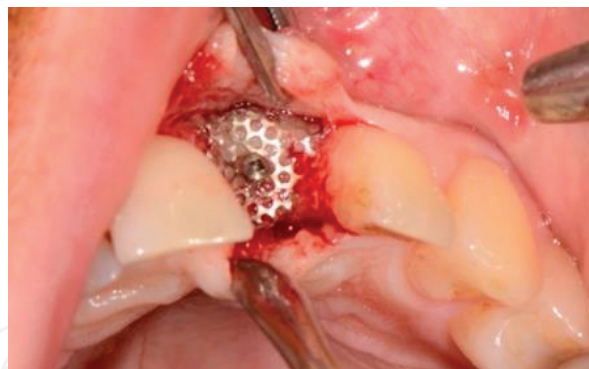


Figure 3.
Titanium mesh was placed on the buccal side and secured into the implant by cover screw.



Figure 4.
After 6 weeks of healing period a mucosa former abutment was placed. The laceratio formed after traffic accident still persist on the buccal mucosa.



Figure 5. Intraoral appearance of implant supported lithium disilicate single crown placed on top of custom zirconia abutment.

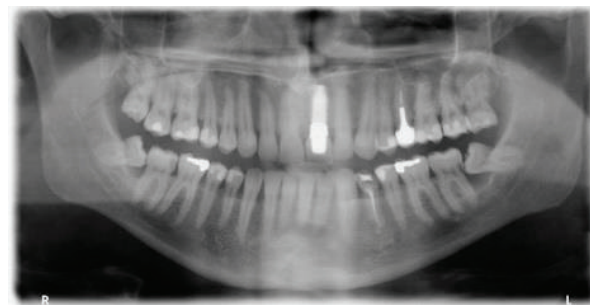


Figure 6. OPG after crown placement.



Figure 7. Appearance after prosthesis delivery: note hypertrophic sequelae of upper left lip due to traffic accident.

effective treatment modality in restoring a patient to near normal function and esthetics. According to this study, maxillofacial injuries made by gunshot create serious esthetic, functional, and psychological consequences. Disabling characteristic of such severe maxillofacial ballistic defects brings the need of challenging extensive reconstructive multiple surgeries and competitive prosthetic rehabilitation phases.

Jain and Baliga [27] described two cases with maxillofacial trauma and had undergone open reduction and internal fixation where implant placement was done for upper anterior teeth.

Sharma and Swamy [28] reported a gunshot case who lost six teeth in maxilla and was rehabilitated by rotated flap, bone grafts and three dental implants supporting a FPD.

Wang et al. [29] mentioned the treatment a 17-year-old boy having maxillofacial ballistic defects. They described multiple techniques for restoration of facial morphology and function. Multiple examinations and surgical procedures including osteomyocutaneous and muscular flaps in combination with dental implants were used to restore facial morphology, functions of mastication and articulation.

Generally implant placement is planned after orthodontic treatment to gain adequate space [21]. But there are exceptions reported depending from the needs and anatomy of individuals such as Kuo et al. [35] who reported a case where after a traumatic loss of upper incisor an implant was placed and subsequent orthodontic treatment was performed.

Kulkarni et al. [36] reported ballistic injury of a 24-year-old man. Maxillofacial deficiency was restored with autogenous iliac bone graft. Following 3 months of healing dental implants were placed. After osseointegration period of 5 months fixed-removable hybrid prosthesis was installed. At the end of third year of hybrid prosthesis usage, it was renewed by a porcelain fused to metal bridge. Follow-up on radiographies showed that the crestal bone levels around implants were stable. Kulkarni et al. [36] stated that the rehabilitation of gunshot injuries is expanded within time and needs several interventions to obtain functional and esthetics requirements.

Seymour et al. [37] mentioned the need of team approach in the rehabilitation severe trauma cases and underlined the importance of communication between general practitioners and specialist especially in the complex dental implant treatments.

Chesterman et al. [38] described guidelines regarding the replacement of single teeth lost due to trauma with implant supported restorations. The protocol proposed includes: evaluation of tooth replacement methods; planning for tooth loss and provision of an implant supported restoration; planning of an implant supported restoration.

Alani et al. [39] stated that with advances in both adhesive technologies and implant dentistry, there are a variety of options for the restoration of edentulism subsequent to TDIs.

Pae et al. [22] described a panfacial fracture case who was managed with a mandibular implant-supported fixed-removable and a maxillary partial removable prosthesis where due to the lack of intraoral landmarks, overall facial anatomic landmarks were used to restore the oral cavity.

Kamoi [40] reported treatment history of a 44-year-old woman who had severe injuries due to traffic accident. The patient got maxillofacial soft tissue lacerations followed by hard tissue fractures, several teeth loss associated with alveolar bone resorption. Several facial reconstructions were made by plastic surgeons. To replace missing upper teeth a sinus grafting procedure was performed by use of a rib bone anchorage and simultaneous placement of five dental implants. After 11 months of healing period, upper overdenture and a mandibular PFM's were fabricated. The outcome of the treatment was found to be satisfactory.

Robinson and Cunningham [41] described the oral rehabilitation of an adult male who suffered severe dentoalveolar trauma as a result of a motor vehicle accident. After extraction of fractured roots, dental implants were placed. Following certain healing period for osseointegration, PFM crowns and FPD's were installed. In a 3-year follow-up period, the outcomes of the treatment were considered to be successful regarding patient's esthetic and functional expectations.

Schneider et al. [42] reported the surgical and prosthodontic rehabilitation of a patient traumatized by a self-inflicted gunshot wound to the mandible which required rehabilitation with a free fibula microvascular graft, single stage dental implant placement, and rehabilitation with CAD/CAM and laser assembled prosthetic components.

Nissan et al. [43] evaluated the outcome of dental implants placed in the post-traumatic anterior maxilla after ridge augmentation with cancellous freeze-dried block bone allografts. After 6 months of healing, implants were placed. The study group was composed of 20 consecutive patients with a mean age of 25 ± 7 years, received 31 implants, 12 of them were immediately restored. Graft and implant survival rates were 92.8 and 96.8%, respectively. There were no changes in bone to implant contact (BIC) levels. The authors considered predictable the usage of cancellous block allografts in the reconstruction of post-traumatic defects of anterior maxilla.

Yamano et al. [44] gave treatment history of a 15-year-old male patient who had a snowmobile accident. Patient got maxillofacial defects and fractures in mid-face and mandible. A multidisciplinary rehabilitation was performed to restore function and esthetics. Treatments involved usage of autologous corticocancellous bone grafts, fixture placement and implant-supported prosthesis fabrication.

A ballistic maxillofacial injury case and her treatment modality was described by Torabi et al. [45] The patient received trauma in maxilla, mandible and nasal areas with heavy problems in her esthetics and functions. Dental implants were used in conjunction with natural abutments to restore dentition.

Bird and Veeranki [46] reported a maxillofacial ballistic injury case rehabilitated with iliac crest bone graft, dental implants, and an economical acrylic resin fixed prosthesis. A 3-year follow-up revealed positive treatment outcomes and it was concluded that although facial gunshots cause severe defects, they can be restored and rehabilitated by a multidisciplinary approach. They outlined the importance of and biomechanical considerations for implant positioning.

Kelly and Drago [12] described a patient who suffered significant trauma to the lower and mid-face secondary to a gunshot injury. The size and severity of the defects are in proportion with the functional and esthetic complications faced during the late phases of the treatment. Regardless to the amount of facial trauma, successful treatment can be performed by appropriate clinical and radiographic examinations and diagnosis followed with correct treatment strategies and applications strictly linked to surgical and prosthodontic principles.

Gökçen-Röhlig et al. [47] described the rehabilitation of a patient with a mandibular defect caused by a gunshot wound who was treated with four osseointegrated implant-supported mandibular overdenture and maxillary removable prosthesis. Despite anatomic limitations, the patient's esthetic and functional demands were fulfilled.

Sándor and Carmichael [48] proposed to respect growth and delay implant reconstruction until the cessation of skeletal or alveolar growth.

In the 2-year follow-up report of a traffic accident and traumatic injury happen to 16 years old male patient who was rehabilitated by autogenous graft and four dental implants, outcomes were found to be satisfactory and stable [49].

Sipahi et al. [50] reported a self-inflicted gunshot maxillofacial defect case who was restored with dental implants and various prosthetic attachments. During short-term follow-up period no complications were occurred. The outcome of a fixed-removable implant-supported mandibular prosthesis and a maxillary obturator was considered successful in the management of a serious traumatic injury.

Clinical evaluation of a mandibular ballistic injury patient was described by Cakan et al. [51]. The patient was treated with cemented crowns for 2 maxillary implants and an implant-supported screw-retained fixed partial denture supported by eight mandibular implants. Although difficulties to properly position the implants because of inadequate bone volume, esthetic and functional demands of the patient were fulfilled.

Schwartz-Arad and Levin [20] examined a patient pool of 53 individuals having dental implants after traumatic injury history in the anterior maxilla. They found

significantly lower complications in the group of patients which did not have inflammatory lesions in their history. Meanwhile patients who lost their teeth due to inflammatory lesions after traumatic injuries got statistically significant amount of complications and failures with dental implants. They underlined the necessity for scrupulous diagnosis of teeth and alveolar bone after a traumatic injury in order to reduce complications and advised individualized treatment planning for each case as the methodology is multidisciplinary.

Schwartz-Arad et al. [21] mentioned the difficulties in the dental implant based rehabilitations in patients who got traumatic injuries in childhood where implant placement is contraindicated during growth period and on the other hand they need replacement of missing teeth and also preserve adequate jaw bone volume for future implant placement. Various treatment strategies were suggested until the end of growth and development. Among them, orthodontic extrusion of the root fragment and a temporary crown application technique in order to preserve alveolar bone, autogenous tooth transplantation, intentional extraction and immediate tooth replantation, distraction osteogenesis, and decoronation could be mentioned.

Five-year follow-up results of 42 single-tooth implant treatment in 34 trauma-related edentulous patients were evaluated by Andersson et al. [52]. In this patient pool the most frequently lost teeth were upper central incisors with an incidence of 75%. In the second place there were lateral incisors with 21% frequency. In growing patients, implant treatment was generally postponed until completion of development. Preservation of roots in the alveolar process seemed to maintain the bone volume enabling better conditions for later implant placement. According to the findings of this study, the functional and esthetic outcome of single-tooth implant treatment can be recommended for replacing tooth losses after trauma in the anterior region of the maxilla.

Tipton [53] reported a case who had TDI due to an accident and rehabilitation protocol with a team approach for dental implant restoration. The outcome was considered excellent regarding the teamwork among the dentist, implant surgeon, and laboratory technician following traumatic injury of the dentition.

4. Prerequisites for dental implant placement after trauma

Systemic conditions and history of the patient should be favorable to the surgery. In the medical history of the patient possible genetic, autoimmune and connective tissue diseases must be investigated in order to reduce risk factors [54]. In the history of patient presence of recent cerebrovascular disturbance and myocardial infarct, ongoing immunosuppressive [55] or chemotherapy, fibrous dysplasia [56–58], intravenous bisphosphonate therapies [59–64], uncontrolled diabetes [65–69], narcotic dependencies or psychiatric diseases form absolute contraindication for dental implant treatment [70]. In such conditions alternative prosthodontic treatments should be planned. Some form of diseases, treatments and drug therapies which affect metabolic activity of body and habits are considered to be relative contraindications as they reduce success and longevity of osseointegration. In the presence of any relative contraindication it must be evaluated the need of dental implant treatment for the patient and health conditions in the decision-making phase. Among relative contraindications there are past radiotherapies with irradiated jawbones [71–74], diabetes, autoimmune connective tissue diseases (rheumatoid arthritis [75–77], Sjögren's syndrome [78], Lupus Erythematosus [79], Papillon-Lefevre syndrome [80–82], Behcet disease, Myasthenia Gravis, Ectodermal Dysplasia [83–87], Skeleroderma [88–90]), calcium-phosphate metabolism disorders and endocrine diseases (osteoporosis, osteopenia, Paget disease, hyper and hypothyroidism, kidney

nephritis, aldosteronism, Cushing syndrome), viral diseases (HIV, Hepatitis III), aggressive periodontitis, smoking, drug abuse, oral bisphosphonate usage, unstable psychological state. Other risk factors which should be evaluated during treatment planning are parafunctions-bruxism and facial dystonia [91].

Animal model studies have shown that metallic implants do not change location in concordance with three-dimensional bony growth [92–95]. Dental implants do not follow bone development during growth period [34, 92–101]. Studies have shown that implants placed in the early ages remain in infra-occlusion by time [99]. For this reason as the consensus, implant treatment is made after confirming bony development period of patient by hand-wrist radiographies and comparisons in radiography-skeleton atlas [98, 100]. Ulnar sesamoid cartilage and middle finger's middle phalanx distal cartilage ossification rate is inspected and compared with images in skeleton atlas. For the minimal age of implant surgery decision instead of chronological age, skeletal age of patient is taken in consideration. Patients who are within the active bone growth period can receive removable prosthesis or adhesive prosthesis. In children adhesive prosthesis such as Maryland type are splinting teeth together and apply stationery anchorage against three-dimensional enlargement of jawbones during active bone growth. Growing patients should periodically controlled and adhesive prosthesis should modify in case of need. In future implant placement plans traumatized roots should be kept in place as space maintainers although their prognosis is poor. Slow orthodontic extrusion of traumatized hopeless roots is one of the bone guidance methods in order to create adequate hard tissue volume for upcoming dental implant rehabilitation [102].

The first prerequisite in implant dentistry is the presence of adequate vital bone volume to entirely cover the implant body [103]. If trauma happens in childhood ending with tooth loose, patient should wait certain years until active bone growth completes before implant placement and during waiting period bone volume decrease in edentulous areas by disuse atrophy. In atrophic crests various augmentation method could be applied. The first choice of augmentation material is autogenous bone grafts. Autogenous bone graft blocks can be placed over recipient residual bone site and fixed by mini-screws, or 'Bone Lamina' technique which consist in splitting a bone block in thin layers and fix them onto the augmentation area by mini-screws as shields to create a certain volume and fill inside the shields with particulate autogenous or synthetic grafts. Autogenous bone grafts are always considered as the golden standard in augmentation procedures. Secondly osteoconductive ceramic alloplast (hydroxylapatite, tricalcium phosphate) or xenografts (bovine, mini-pig, single-hoofed) are preferred. Demineralized, demineralized freeze-dried or frozen homolog transplants although are osteoinductive they have non-predictable life-time and may not be adequate to complete osteogenesis phases in time scale. Other augmentation alternative is the usage of titanium grid-mesh (Ti-mesh) shields to obtain tent effect and fulfill them by particulated graft materials. Similarly, Guided Bone Regeneration (GBR) technique can be applied by use of resorbable or non-resorbable membranes alone or in conjunction with graft materials according to the defect size. Split-bone technique is suitable for crests thicker than 3 mm in buccopalatal section and mainly is adequate for pliable maxilla rather than less elastic mandible. Crestal bone is splinted in equal two pieces by micro-saws, piezoelectric inserts or Erbium Yttrium Aluminum Garnet (Er:YAG) laser until bypassing cortical bone. Once spongy bone is arrived special splitter osteotome inserts are placed into osteotomy site. To avoid unpredictable fractures vertical release osteotomies should be made in the extremities of the working field. Distraction osteogenesis is another technique well documented for bone augmentation. But distraction appliances are difficult to maintain for children in the interactive play age and could be further traumatized often.

The choice of augmentation method depends on the defect size, volume, tridimensional shape of hard tissues and biotype of soft tissues. If the vertical dimension of the crest is normal but bucco-palatal width is missing GBR, Ti-mesh, Split-bone, onlay graft, Bone Lamina techniques could be used. When the vertical bone height is lost onlay grafting, Bone Lamina, distraction osteogenesis and Ti-mesh would be preferences. Soft tissue thickness establishes biotype of mucosa. Thin biotypes are difficult to manage as they are fragile and difficult elongate in order to achieve tension free flap. Flaps which cover wound should be overlay on grafted area without pressure in order to obtain normal blood supply. If there would be several tensions on the flap, vascular network will suffer and due to the lack of nutrition surgery can fail. Flap design gain certain importance to have profuse blood circulation. Flaps with larger base than free edge, possibly without vertical release incisions can maintain vascular network without interruption of capillary arteriae and vessels. Anatomic studies have shown that within the buccal and palatal mucosa, capillary networks do not constitute anastomosis on the top crestal region of maxilla and mandible [104]. Thus by mid-crestal incisions there is no interruption of vessels and this type of incision should be choice of preference. Mucosal flaps according to depth could be 'full-thickness' where epithelium, connective tissue and underlying periosteum are excited and elevated together; or 'split-thickness' where periosteum is left attached to the cortical bone to avoid blood supply interruption (because capillary arteriae network is situated within the periosteum and 70% nutrition of the cortical bone derives from periosteum), and to have elasticity of the flap (periosteum do not have elastic behavior). Thick biotype mucosa has an advantage in terms of elongation. To elongate a full-thickness flap the basal portion of it which is constituted by periosteum should be gently incited horizontally. In such manner the rigidity of the periosteum is alternated and underlying connective tissue portion would elongate easily as contains elastin fibers of collagen. Split-thickness flaps could be preferred only in thick biotype mucosa as the thin biotype is difficult to split and fragile.

Implant's primary stability is another prerequisite to achieve osseointegration. Studies have shown that dental implants can integrate with surrounding bone if they have less than 100 microstrain or less than 150 micron micromovement [105–109]. Early loading of dental implants do not interfere with surrounding bone mineral apposition speed and osteogenesis phases continues to integrate with implant surface if primary stability is achieved [105–111]. Osteoblast phenotype morphology and physiology are not altered in immediately or early loaded implants [108, 110]. Adequate primary stability for a dental implant could be interpreted by insertion torque values greater than 30 N/cm². Primary stability and in the following time period stability of implants could be measured by use of Resonance Frequency Analysis (RFA) method [112–114]. RFA works by vibrations transmitted to implant body and measurement of implant's resistance values in numbers expressed in Implant Stability Quotient (ISQ) units. Studies conducted with RFA showed that peri-implant bone strength follows Normal Distribution Curve (bell curve) as seen in many natural phenomena. Initial strength of interfacial bone to the implant due to inflammatory reactions and acidic environment decreases and reach the weakest point in the third week after implant placement. Meanwhile mineral apposition and developing ossification take place and secondary stability increase after third week to reach initial stability ISQ values approximately in the sixth week. The studies made on micro-movement and micro-strain have shown the possibility of osseointegration in immediate loading situation unless the threshold of 100 micron of mobility is not exceed [105–107]. Based on such results, it has been introduced 'immediate loading' protocol by use of splinted implants for totally edentulous patients [106, 109]. There are promising results and developing

protocols of immediate loading for partially edentulous and missing single-tooth cases, where the requirements are presence of primary stability more than 30 N/cm^2 , implant length more than 10 mm, implant diameter more than 3.75 mm for titanium or zirconia dental implants and 3.3 mm for titanium-zirconia alloy implants, rigid splint of implants (in partially edentulous cases), non-functional loading, temporization (immediate delivery of provisional crowns or bridges to shape soft tissue contours). In patients where there are short implants but adequate primary stability, or patients with parafunctions, patients with low density bone (type III or IV), 'early loading' protocol which previews 6 weeks healing period can be applied. If the primary stability of an implant is less than 30 N/cm^2 insertion torque, healing period should be elongated to 3 months for the lower and 6 months for the upper jaw bones which is called 'delayed loading' protocol as proposed by Branemark at the beginning years of modern scientific implant dentistry.

TDI cases mostly involve anterior maxilla with early or delayed loss of single tooth (except gunshots) which is mainly central incisor. In single-tooth replacements there are special rules to follow in order to obtain suitable esthetics. Maintenance of soft tissue envelope contours and the presence of papillae are highly important. The preservation of soft tissue integrity is related to flap nutrition, thus flapless surgery is the primary choice. The 'tunnel technique' may be an alternative to conventional open flap surgery and graft application, in order to apply minimally invasive surgery. Another approach is to avoid vertical release incisions and apply only sulcular incision to keep intact vessels of flap and cause less reduction of blood supply.

Papilla protective flap design is thought to preserve papillae, where two vertical incisions exclude papillae in both distal and mesial sides and a narrow full thickness flap band is raised. In long term follow-ups it has been noted that those two vertical incisions lead the formation of scar areas which would be apparent on the buccal side of mucosa. On the other hand, in case of intra-operative treatment plan change, upon need of augmentation, the graft materials would be under incision lines. The presence of incisions on the grafted area will increase microbial contamination risk of graft by micro-leakage and cause inadequate blood supply to the graft. Thus, papilla protective flap design is almost a disappeared technique.

The second rule to follow in single-tooth replacements is the preservation of buccal bony wall. In jaw bones anatomy, buccal portion of alveolar bones is mostly very thin [115–117]. This thin buccal wall would be resorbed rapidly due to acidic inflammatory environment which may take place in case of nutrition lack due to flap raising, or after trauma and post-traumatic extraction where crestal bone could be fractured. To avoid traumatic extractions periostomes, electro-dynamomagnetic device inserts, piezoelectric device inserts, special extraction drill-chain appliances, very thin Er:YAG laser sapphire tips are developed. 'Ridge preservation' techniques which aims to immediately graft extraction sockets to avoid future resorptions are proposed. Some authors proposed not only hard tissue grafting but also mucosa transplants by punch technique to cover entirely socket orifice. On the horizontal plane palato-position of the implant placement is another rule to follow to preserve buccal width of alveolar bone. Palato-position of an implant is obtained by centering the insertion point of first drills on the palatal wall of the socket, but not to the apical bottom; the location should be slightly palatal to the inter-incisal line of adjacent teeth. Palato-positioning helps also to balance the future unavoidable senile resorption pattern of buccal alveolar bones which is physiological. A single-tooth implant should keep equal distance to the neighboring teeth. The collar platform level of the single-tooth implant should not be embedded more than 2 mm apically from the cemento-enamel junction (CEJ) of adjacent teeth. If the implant collar exceeds CEJ criteria, longest crowns in comparison to natural dentition should be

fabricated and the future bacterial colonization of inner implant spaces will execute pumping effect of contaminants deriving from the micro-gaps between abutment-implant connection during chewing cycles which will result in collar area bone resorption and subsequent mucosal recessions and papilla loosening.

In adolescent patients who completed their skeletal growth and in adults after traumatic loss of teeth if the available soft tissue and bone volumes are favorable, implants could be placed immediately. Immediate implant placement may be excluded when the soft tissues have lost their integrity to cover wound area by tension-free flaps; or when hard tissues have great volume loss and primary anchorage possibility would poor (e.g., traffic accidents, gunshots). In such situations primary wound healing should be waited. The risk in immediate implant placement after trauma is associated with the contamination of defect area by foreign bodies and microorganisms. To clean extraction socket generally conventional curettage is followed. But bacterial contamination can still persist within the lamina cribrosa of socket or in the spongy bone. The best method to avoid contaminants and bacteria from the wound area would be usage of Er:YAG laser irradiation associated with conventional curettage as the studies have shown Er:YAG's high bactericidal effect against microbiota [118–120].

In the anterior region of jaws titanium implant body and abutment reflection may be apparent by time as buccal bone senile resorption pattern is from distal (outside) to medial (inside). Solution to mask metallic reflection is the usage of ceramic materials. Recently full ceramic zirconia implants and abutments gained again popularity. After first attempts of alumina implants in the 1970s and their mechanic failures caused an interval of approximately 30 years. In last two decades, firstly CAD/CAM zirconia abutments and following one-piece zirconia and recently two-pieces zirconia implants were introduced in the market. Nowadays most sophisticated applications of single-tooth replacements are made by full ceramic implants, zirconia-titanium or titanium implants and zirconia abutments supporting leucite-reinforced ceramic or lithium disilicate ceramic crowns.

Future trends and strategies in dental traumatology in general and with special attention to dental implant applications are based on the education of population in terms of emergency treatments and urgent transport of patients to the clinics; trained clinics on emergency treatments; preparation of patients to future implant rehabilitations by interim treatment which care preservation of hard and soft tissues.

5. Conclusions

Edentulism due to trauma could be properly rehabilitated by dental implant placements. Reports in the literature have been adequately evidenced safe usage of dental implants after traumatic injuries. There are various considerations to plan suitable treatment option in the edentulous areas of jawbones after trauma. At the first side the systemic conditions of patient should permit dental implant surgery. Secondly the skeletal age of patient should be adequate to implant placement as it is shown that implants do not migrate following bony development and embed in an infra-occlusion by time. The third level of consideration is the availability of soft and hard tissues. Rehabilitation strategies are developed according to the defect size, volume, tridimensional shape of hard tissues and biotype of soft tissues. Special attention is paid to preserve mucosal contours and papillae by use of flapless technique or proper incisions, as well as hard tissue augmentation options are planned taking in consideration the available vascularity, defect wall number, bone height and fixation of graft material. In the implant placement phase the primary

stability is the main target in order to initiate osseointegration. There are several implant insertion techniques such as drilling, narrow drill/wider implant, osteotome, bone splint and laser-assisted which are decided basing on possible primary anchorage within the residual bone. After achievement of primary stability it should be decided the loading type of implants which is related to implant number, localization, length, diameter, splinting options. Basically functional immediate, non-functional immediate, early or delayed loading protocols can be applied. Once loading protocol is fixed it should be emphasized the prosthetic supra-structure design and material. In conclusion missing teeth due to trauma could be successfully rehabilitated by dental implants following detailed and careful diagnosis in order to establish proper individual treatment plan and by application of consecutive treatment steps.

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