INDIVIDUAL DEVELOPMENT PLAN FOR THE MASTER’S THESIS

Graduate student Abdennour Taimour

of the year 2017, and the group 14 of the integrated study program of Odontology

Duration of studies from ________________ till ________________

Supervisor Dr. Sandra Žemgulytė

MT title: permanent tooth autotransplantation in paediatrics as a treatment alternative- systematic review

MT annotation:

______________________________________________________________________________

______________________________________________________________________________

Aim of the work:

Aim is to review whether permanent tooth auto-transplantation can be considered as predictable treatment alternative in pediatric patients who lost/miss permanent tooth.

Tasks of the work:

. Analyzing recent clinical data and discussing different clinical key factors that might alter or enhance success and survival rates of this treatment.

. Drawing a brief comparison with other standard treatments carried out in pediatrics to appreciate the uniqueness of teeth auto-transplantation.

. Deducing if this treatment can be considered as predictable treatment alternative in pediatrics.

Schedule of the works

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<th>No.</th>
<th>Description of MT task</th>
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<td>2017/09/01</td>
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<td>2</td>
<td>Methods: protocol and registration; eligibility criteria; information sources; search, study selection, data collection process; data items; risk of bias in individual studies; summary measures, synthesis of results; risk of bias across studies; additional analyses.</td>
<td>2017/10/30</td>
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<td>Results: Study selection; Study characteristics; Risk of bias within studies; Results of individual studies; Synthesis of results; Risk of bias across studies; Additional analysis.</td>
<td>2017/11/30</td>
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<td>4</td>
<td>Introduction: Rationale; objectives</td>
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<td>5</td>
<td>Discussion: Summary of evidence; Limitations; Conclusions</td>
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<td>6</td>
<td>Abstract: Structured summary: Objectives; Data sources; Study eligibility criteria; Study appraisal and synthesis methods; Results; Limitations; Conclusions and implications of key findings; Systematic review registration number.</td>
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Graduate student’s name, surname and signature Abdennour Taimour

Supervisor’s name, surname and signature Dr. Sandra Žemgulytė
Permanent tooth auto-transplantation in pediatrics as a treatment alternative – A systematic review

Master thesis

Supervisor
DMD Sandra Žemgulytė

Kaunas, 2018
Permanent tooth auto-transplantation in pediatrics as a treatment alternative – a systematic review

Master’s thesis

Thesis was done
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Supervisor ………………………

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EVALUATION TABLE OF THE MASTER’S THESIS  OF THE TYPE OF SYSTEMIC REVIEW OF SCIENTIFIC LITERATURE

Evaluation:................................................................................................................................................
Reviewer:..................................................................................................................................................
(scientific degree. name and surname)
Reviewing date: .............................................................

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<td>Are the problem, hypothesis, aim and tasks formed clearly and properly?</td>
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<td>Are the aim and tasks interrelated?</td>
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<td>Are all the information sources (databases with dates of coverage, contact with study authors to identify additional studies) described and is the last search day indicated?</td>
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<td>Selection criteria of the studies, search methods and strategy (3.4 points)</td>
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<td>Is the selection process of studies (screening, eligibility, included in systemic review or, if applicable, included in the meta-analysis) described?</td>
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<td>Is the data extraction method from the articles (types of investigations, participants, interventions, analysed factors, indexes) described?</td>
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<td>Are all the variables (for which data were sought and any assumptions and simplifications made) listed and defined?</td>
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<td>Are the methods, which were used to evaluate the risk of bias of individual studies and how this information is to be used in data synthesis, described?</td>
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<td>Is the number of studies screened: included upon assessment for eligibility and excluded upon giving the reasons in each stage of exclusion presented?</td>
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<td>Are the characteristics of studies presented in the included articles, according to which the data were extracted (e.g., study size, follow-up period, type of respondents) presented?</td>
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<td>Are the evaluations of beneficial or harmful outcomes for each study presented? (a) simple summary data for each intervention group; b) effect estimates and confidence intervals</td>
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<td>Are the limitations of the performed systemic review discussed?</td>
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<td>Does author present the interpretation of the results?</td>
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<td>Do the conclusions reflect the topic, aim and tasks of the Master’s thesis?</td>
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<td>Are the links of the references to the text correct? Are the literature sources cited correctly and precisely?</td>
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<td>Is the scientific level of references suitable for Master’s thesis?</td>
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<td>Do the cited sources not older than 10 years old form at least 70% of sources, and the not older than 5 years – at least 40%?</td>
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**Additional sections, which may increase the collected number of points**

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<td>Were additional methods of data analysis and their results used and described (sensitivity analyses, meta-regression)?</td>
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<td>+0.5</td>
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<td>Was meta-analysis applied? Are the selected statistical methods indicated? Are the results of each meta-analysis presented?</td>
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### General requirements, non-compliance with which reduce the number of points

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<td>15-20 pages (-2 points)</td>
<td>&lt;15 pages (-5 points)</td>
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<td>Is the thesis volume increased artificially?</td>
<td>-2 points</td>
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<td>Does the thesis structure satisfy the requirements of Master’s thesis?</td>
<td>-1 point</td>
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<td>36</td>
<td>Is the thesis written in correct language, scientifically, logically and laconically?</td>
<td>-0.5 point</td>
<td>-1 points</td>
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<td>37</td>
<td>Are there any grammatical, style or computer literacy-related mistakes?</td>
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<td>-1 points</td>
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<td>38</td>
<td>Is text consistent, integral, and are the volumes of its structural parts balanced?</td>
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<td>-0.5 points</td>
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<td>Amount of plagiarism in the thesis.</td>
<td>&gt;20% (not evaluated)</td>
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<td>Is the content (names of sections and sub-sections and enumeration of pages) in compliance with the thesis structure and aims?</td>
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<td>41</td>
<td>Are the names of the thesis parts in compliance with the text? Are the titles of sections and sub-sections distinguished logically and correctly?</td>
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<td>42</td>
<td>Are there explanations of the key terms and abbreviations (if needed)?</td>
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<td>Is the quality of the thesis typography (quality of printing, visual aids, binding) good?</td>
<td>-0.2 point</td>
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*In total (maximum 10 points):*

*Remark: the amount of collected points may exceed 10 points.*

Reviewer’s comments:

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Reviewer’s name and surname | Reviewer’s signature
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ABBREVIATIONS

CR – Case Report;
CT – Clinical trial;
N – Number;
Y – Year;
M – Month;
P – Patient;
AT – Auto-transplantation;
prM – Premolar;
U – Upper;
Lo – Lower;
Ce – Central;
L – Lateral;
Ca – Canine;
Pr – Primary;
I – Incisor;
(-) – Missing data;
AT – Autotransplantation;
Conv – Conventional;
Alv – Alveolar;
X – Extraction;
Surg – Surgery;
Type – Types of splints.
SUMMARY

Aim: to deduce if permanent tooth auto-transplantation can be considered as predictable treatment’s alternative in pediatrics, by analyzing recent clinical reports in order to compare different key factors that might alter or enhance success and survival rates of this procedure.

Material and methods: study was conducted by one investigator according to PRISMA-Protocol. 231 studies (published 2007-2017) were collected from PubMed, Research Gate, and Willey Online Library databases, between June and December 2017. 203 articles were excluded during screening and eligibility due to duplicates, non-English, non-human, used on adults, in vitro, or lacking clinical data. Leaving 28 clinical trials/case reports according to PICOS and inclusion criteria such as patients’ age < 18 years old and follow-up > 0.5 years.

Results: In total 321 patients were included. The mean age of patients was 11.6 years (4.8-18 years old). Overall 398 teeth were auto-transplanted (85% were premolars), mainly due to experienced severe dental trauma or congenital absence of permanent tooth. A majority of teeth healed uneventfully while some exhibited complications such as root resorption, pulp necrosis and arrested root development. The success and survival rates of auto-transplants ranged from 60% to 100% and from 87 to 100%, respectively during a follow-up period ranging from 0.5 to 21 years.

Conclusions: Tooth auto-transplantation as a treatment method showed that its success and survival rates could be very high and predictable as any other conventional treatments. And even though, an auto-transplant failure could occur, it could serve as a temporary solution preserving bone and soft tissue dimensions until finished skeletal growth for future easy implant placement.

Key words: dental/tooth, auto-transplantation/ autogenous transplantation; pediatric/child.
INTRODUCTION

Autogenous permanent teeth transplantation can be associated with a mindset of “optimism and success” for some practitioners while “pessimism and failure” for others. This clearly opposing perspectives date back to 1594 when the permanent tooth transplantation started as allogeneic teeth transplantation, documented by Ambroise Paré, and still controversial up till our modern time due to implants popularity and their lucrative business. Even though, during the last decades, and while facing many critics from many dentists worldwide, this controversial treatment option has been studied and improved covering all its aspects starting from patient selection to post-operative care.

Generally speaking, by definition, an autogenous tooth transplantation is the surgical movement of a donor tooth from its own socket to a recipient socket within the same mouth. Surgically speaking, it is an intentional and well planned sterile, atraumatic, surgical avulsion of a donor transplant followed by its re-implantation into a pre-existing or prepared recipient socket within same mouth, while respecting all the surgical aspects for a successful prognosis.

This being said, auto-transplantation is not a new surgical method, but rather a very old practice which all began as allogeneic tooth transplantation, meaning that a tooth is taken from one mouth and transplanted into another, this has been reported in the ancient Egypt civilization where slaves were forced to offer their teeth for their pharaohs, but due to complications this method was abounded. The first of its kind has been scientifically reported back to 1594 carried on the royal French family. But, it was until 1772, that surgeon John Hunter ‘succeed’ in allo-transplanting a tooth, which has created a controversial debate due to huge lack of knowledge about transmissible diseases and immune compatibility.

200 years later, the first scientific research about autogenic transplantation, took place in late 1970s on monkeys, taking into consideration several key factors such as biological principles like damage to Hertwig’s epithelial root sheath during extraction, its periodontal ligament cells survival, extra-alveolar time of donor tooth, its position within its future recipient socket, as well as the post-surgical splinting methods. Few years later, in Copenhagen university, where one of the most important studies was achieved with a sample size of 370 autogenic transplanted premolars that were included into a prospective study with patients from 7-35 years of age. And since then, numerous studies were done on humans and reporting success rate ranging between 75-98%, including a sample size of up to 291 teeth with a long follow up period to up to 41 years.

Getting into the permanent teeth auto-transplantation itself which is subdivided into 4 mains categories. The most common is conventional type which is defined as moving surgically the donor
tooth from one socket to another within same mouth. Second type is trans-alveolar in which a severely impacted tooth can be surgically extracted to be repositioned into its surgically prepared socket within the dental arch in proper occlusion. The third type is intra-alveolar which is surgical extrusion, rotation and/or, up-righting. Finally, intentional replantation type which is very familiar among dentists to solve an avulsion or an endodontic problem that can’t be treated by a conventional non-surgical approach.

On one hand, when opting for a conventional auto-transplantation, some main indications among others must be fulfilled such as loss/congenital absence of permanent tooth in pediatric patient due to several etiologies. Mainly noticed in the first permanent molar that erupts early, encountering many pathologies and heavy restoration which eventually cause its early loss leading to malocclusion and loss of bone dimension. Thus, auto-transplantation of an immature wisdom tooth at that socket might be a solution. Another indication is maxillary incisors trauma or cleft lip/palate that causes severe teeth deformation/ectopy/loss. In such cases, incisors could be replaced by patient’s own premolars. In cases of cleft, both lips and alveolar ridge repair is necessary prior to auto-transplantation. One more indication for tooth auto-transplantation is agenesis or congenital absence whose treatment options can include orthodontic closure, space maintainer by removable prosthesis for future implant, or auto-transplantation. the key factors determining the best option will be discussed later on in this paper.

On the other hand, the contraindications might be several, including patient’s own medical condition prior to surgery which must be optimal or at least controlled, any poor oral hygiene can compromise the infection-free surgical site, uncooperative and non-motivated child is a critical factor since auto-transplantation is a very sensitive surgical procedure with a long post-operative therapy necessitating multiple visits for both the post-surgical follow-up and for the possible orthodontic and prosthodontic treatments, last but not least lack of presence of donor tooth that can be used as transplant.

Unlike other treatments, the main advantages of this treatment for pediatric patients are: the auto-transplanted tooth continues to erupt into occlusion (3 to 24 weeks after transplantation) as its root development continues, while stimulating a followed formation of new surrounding alveolar bone to sustain its proper height and width to cover the root, simultaneously the soft tissues like periodontal ligaments and gingiva are evolving and creating natural red-esthetic contouring especially in anterior maxillary esthetic area. Besides, auto-transplant functions like a normal tooth by providing normal proprioception and thermal sensation, as well as it can be moved orthodontotically, unlike implant whose position is fixed and osseointegrated. Another pro is no
need to damage the adjacent sound teeth for a fixed prosthesis. Even though, complications occur for instance arrested root development or ankylosis, the auto-transplant is able to prevent the alveolar bone resorption, preserving good bone dimension for future osseointegrated implant after facial growth is completed. Moreover, Treatment is cost-effective by being cheaper than alternative prosthetic restorative and/or orthodontic treatment options. However, the main disadvantages and limitations that can jeopardize the predictable results and high success rate of this technique is the fact of long and proper communication between a multi-disciplinary team specialists, patient commitment to a long-standardized follow-up, technique sensitive which necessitates an experienced surgeon, and an ideal patient’s age should be between 9-12 years before growth spurt finishes. Last but not least, medically fit patient with a healthy donor tooth which once extracted will not compromise the occlusion integrity.

Every auto-transplantation surgery is complemented with an orthodontic movement of transplant which is necessary in most of the cases to correct and bring the tooth to an ideal position within the arch and into occlusion. Unfortunately, pulp complications can develop causing pulp necrosis and periapical pathologies. In these cases, endodontic treatment must be carried out to induce pulp regeneration or apexification in immature roots. Seldom, a periodontal treatment is necessary, which can be in form of dressing post-surgically or correcting soft tissue defects. Later on, when the bone, periodontal ligament and root properly developed, a prosthodontic treatment can be initiated to establish an esthetic and functional tooth such in cases where a premolar is auto-transplanted in socket of central maxillary incisor. Last but not least, antibiotic therapy which can be used as prophylaxis or as post-operative necessity. The dosage and period vary depending on the case and country’s regulations.

Finally, every dental procedure’s popularity and usage depend directly on its success and survival rates. And even though permanent tooth auto-transplantation is getting a lot of attention during the last decades, it still has limited published data on how successful this treatment is in order to be accepted as a standard treatment option with a predictable outcome on pediatric patients.

Aim is to review whether permanent tooth auto-transplantation can be considered as predictable treatment alternative in pediatric patients who lost/miss permanent tooth. By implementing the following tasks:

- Analyzing recent clinical data and discussing different clinical key factors that might alter or enhance success and survival rates of this treatment.
- Drawing a brief comparison with other standard treatments carried out in pediatrics to
appreciate the uniqueness of teeth auto-transplantation.

Deducing if this treatment can be considered as predictable treatment alternative in pediatrics.
SELECTION CRITERIA OF THE ARTICLES.
SEARCH METHODS AND STRATEGY.

This systematic review was conducted in accordance with the PRISMA-P (*Preferred Reporting Items for Systematic review and Meta-Analysis Protocols*) recommendations to analyze and determine whether or not the permanent tooth auto-transplantation should be considered as a treatment option in pediatrics. (Annex A)

3.1. Selection criteria.
The systematic review protocol was prepared regarding the PRISMA-Protocol, and eligibility criteria were defined according to PICOS (Annex A). Besides, inclusion and exclusion criteria and filters covered the following statements:

Inclusion criteria: 1) under 18 years of age with indication for tooth auto-transplantation; 2) clinical trials and case reports as study designs for selection; 3) follow-up period >0.5 year; 4) articles published in 2007 and later; 5) language: English; 6) species: humans; 7) studies *in vivo*.

Exclusion criteria: 1) non-full articles or inaccessible full articles unless purchased; 3) literature review and systematic review; 4) studies enrolled both children and adult patients as participants; 5) participants older than 18 years; 6) lack of relevant details (root development stage, surgical procedure, follow up period, etc); 7) studies using other methods/techniques for tooth auto-transplantation (cryo-preservation); 8) species: animals; 9) studies *in vitro*; 10) non-English articles; 11) articles in which traumatic teeth were treated endodontically prior auto-transplantation was planned; 12) follow-up period <0.5year.

3.2. Search strategy.
The search of publications was performed by one investigator, who selected, screened, and verified the collected material’s eligibility. This search was undergone from June till December 2017, and was conducted through Pubmed, Research Gate, and Wiley Online Library databases. To fully access these databases and gather full text articles, the usage of LSMU’s EZPROXY was necessary. In addition, the following key words and their different combinations were used dental/tooth, auto-transplantation/ autogenous transplantation; pediatric/child.

The search was later on complemented by a manual review of articles and references of the gathered material. Further on, the final articles collected for systematic analysis was then double-checked by the supervisor (Sandra Žemgulytė).
3.3. Study selection.
During the search identification phase, access to the databases was granted, insertion of different combinations of the key words mentioned previously, as well as the activation of the filters as mentioned in inclusion criteria (year of publication 2007 and later; humans; *in vivo*; English; study design: clinical cases, case reports; full text) was done. A sum of 231 articles was collected from the three mentioned databases, to exclude 43 duplicates; the remaining 188 articles were then screened to exclude 91 articles (due to lack of details, other study designs, and other languages). Later on, 97 full-text articles were assessed for eligibility, 56 of them were excluded (due to mixed pediatrics and adult patients, only adult patients, *in vitro*, and earlier than 2007). The 41 articles left for the qualitative synthesis were analyzed further to exclude 13 articles (due to using different surgical protocols like cryosurgery). Finally, ending up with 28 articles that were included in this systematic study analysis.

3.4. Data extraction.
In this stage, data extraction was done as shown in annex B - tables (1), (2), and (3), by manual review, reading and selecting the main details which were considered key factors in the teeth auto-transplantation treatment. The aim was to gather enough clinical data in a way a full and clear comparison between different studies can be made to analyze and understand how each prognostic factor affects or not the main variables (success and survival rates) of the permanent tooth auto-transplantation.

Data extraction was displayed in annex B – table (1) as a brief definition of different types of autotransplantation, their indications, surgical protocol, and criteria of success.

Then, in table (2): 1) researcher and year of publication; 2) study design; 3) number of patients; 4) number of teeth; 5) age range; 6) number of transplanted/donor tooth; 7) auto-transplantation recipient site; 8) root development stage (according Moorrees classification); 9) reason for auto-transplantation; 10) follow-up period; 11) complications; 12) success rate; 13) survival rate.

Lastly, further detailed data extraction was focused on the treatment phases, as shown in annex B - table (3): 1) surgical treatment (type of auto-transplantation, extra-alveolar time and storage; suture; splint); 2) endodontic treatment; 3) periodontal treatment; 4) orthodontic treatment; 5) prosthodontic treatment; 6) anti-biotic treatment.

3.5. Study variables
In this study, the main two variables were success and survival rate of the conventional auto-transplanted permanent teeth depending on different key factors such as stage of root development and surgical protocols. On one hand, the *success rate* was defined slightly different in some of the
selected studies. But to simplicity purposes, the success criteria (annex B - table 3) have been standardized in this systematic review to include: 1) Pain-free transplant; 2) No percussion sensitivity; 3) Positive cold test (6 months post-surg.); 4) Normal chewing, 5) Grade-I tooth mobility; 6) X-ray: continuous root development (crown:root ratio <1, normal lamina dura), pulp canal obliteration, no progressive root resorption, no pathologies (6-9m post-surg): ankylosis or any type of root resorption, new bone regeneration around transplant, normal healing of recipient alveolus (3m post-surg.); during oral examination- normal periodontal tissues: depth of sulcus<3mm, gingival contour, and gingival color. On the other hand, when it comes to survival rate, it was defined as the presence of the auto-transplanted tooth during the follow-up period (>0.5 year) with any complication that could be treated without leading to transplant loss.

3.6. Risk of bias in individual studies.

Unfortunately, among other limitations, the risk of bias has not been fairly paid attention to in few of the selected studies for this paper, which in its turn could have caused a fair level of bias across studies. This should be taken in consideration while reading this systematic review. Besides, no tool has been used to assess risk of bias neither for example ROBIS. In other words, the selected studies can give an over-estimation of the good outcomes of permanent tooth auto-transplantation treatment, which might not reflect the clinical truth. However, this doesn’t mean that permanent tooth auto-transplantation as a treatment method has a misleading prognosis, especially if a professional judgment is based on the clinical data here presented.
Records identified through PubMed database searching (n = 36)

• 36 articles identified through PubMed database searching

Records identified through Wiley Online Library database searching (n = 80)

Records after duplicates removed (n = 43)

Records screened (n = 188)

Records excluded:
- 28 lacking details
- 53 other study design
- 10 other languages (n = 91)

Full-text articles assessed for eligibility (n = 97)

Full-text articles excluded, with reasons:
- 4 in vitro
- 31 adults only
- 14 adults & kids
- 7 about kid but earlier than 2007 (n = 56)

Studies included in qualitative synthesis (n = 41)

Studies for systematic analysis (n = 28)

Records excluded:
- Other methods (ex: cryosurgery) (n = 13)
SYSTEMIZATION AND ANALYSIS OF DATA

All extracted data has been displayed in form of tables 1, 2, and 3 in Annex B. Starting with table 1, which explains and shows briefly the types of permanent tooth autotransplantation carried out in all the studies covered by this systematic review. Noticing that the conventional auto-transplantation was the most popular variant (in 23 studies), coming in second trans- and intra-alveolar auto-transplantation with 2 studies each, while the least common was the intentional re-implantation with 1 study only. Alongside the mention of these variations, a brief definition and indications were implemented to help the reader to distinguish and understand the most suitable type for each clinical case. Simultaneously, a brief surgical protocol was added to have an idea about the treatment itself, as well as simplified success criteria, were deemed necessary to create a complete picture on how this treatment’s outcomes should be, clinically speaking.

As in table 2, the general findings from the articles were presented. In this systematic review 19 publications were case(s) reports and 9 were clinical trials. The mean number of participants in the studies was 12 (ranging from 1 to 79). Their mean age was 11.6 years old (ranging from 4.8 to 18 years). The reasons for the permanent tooth auto-transplantation were several, most commonly were: dental trauma (like crown-root fracture, ankylosis, or avulsion due to an accident, etc.) (15 studies), congenital absence of permanent buds (including Clef Lip & Palate) (8 studies), severe impaction (6 studies), and few others like severely complicated caries (3 studies), abnormal morphology (2 studies), conventional ameloblastoma (1 study), odontoma (1 study). The mean score of teeth-sample size was 15 teeth (ranging from 1 to 111), whereas the most common autotransplanted teeth were the premolars (N-338; 19 studies); molars (N-47; 9 studies). Consequently, the least common were incisors (N-10; 5 studies) and canines (N-3; 2 studies). Mostly, donor teeth were autotransplanted during the 3rd – 4th root development stage (reported in 20 studies), while it varied from 2nd till 6th in the remaining studies.

In this systematic review 19 articles reported post-operative complications, for instance root resorption (7 studies), pulp necrosis (5 studies), arrested root development (5 studies) and ankylosis (2 studies) which were diagnosed during follow-up period, while the results of remaining studies healed uneventfully (NB! pulp obliteration was considered as a positive sign for vital pulp reaction, not a complication). Moreover, the mean follow-up period of developed complications was 4.26 years (ranging from 0.5 to 21 years).
The last components in table (1) were success and survival rate showing the effectiveness of this treatment method. Their outcome’s variation depends on some prognostic factors, which will be discussed further on. A simplified definition of both success and survival rate has been implemented because of the fact that these studies had no uniformity in the criteria used to describe the terms success and survival of the auto-transplanted teeth. The success rate definition was based upon the criteria that most studies mentioned, clinically: vital transplant during follow-up, painless, no percussion sensitivity, physiological mobility, and normal periodontal tissue. While radiographically, continued root development, no peri-apical pathologies, crown-root ratio <1, canal obliteration. In most cases the value of the success rate was 100% (18 studies), while the remaining studies varied from 80-96% (8 studies), and from 60-73% (2 studies). And finally, the survival rate which was basically defined as the presence of the tooth during the follow-up period with treated complications if present, giving a maximum rate of 100% (25 studies), and high rate ranging from 87 – 97.2% in the remaining 3 studies.

Last but not least, in table 3, the whole auto-transplantation treatment was divided into 6 main moments: surgical, endodontic, periodontal, orthodontic, prosthodontic, and pharmaceutical treatments. The main aspects of surgical protocol were analyzed such as type of auto-transplantation, extra-alveolar time, extra-alveolar storage, suturing, and splinting. Surgical phase is the most crucial aspect of auto-transplantation during which many key factors come into play. Any changes or adjustments of this surgical protocol might either enhance or alter the healing process. Results showed that the most prevalent type was conventional auto-transplantation (24 studies), while the other types were less common like an intra-alveolar (3 studies), trans-alveolar (3 studies) and intentional replantation (1 study), respectively. After analyzing the extra-alveolar time, the most common was “straight” implantation into the recipient site without extra-alveolar time which means that the donor tooth has been extracted and left in its socket while preparing the recipient site (8 studies); then storing the transplant in a media for <5min (4 studies), for <10min (4 studies), and for <15min (2 studies); while the rest of the 10 studies provided no data. Choosing saline as a physiologic medium in which the donor teeth with extra-oral time has been kept, was the most common solution (7 studies), while 1 study reported the mixing of 100 mg doxycycline, 4 mg dexamethasone, and 10 ml saline in which 20 teeth has been stored, the remaining studies lacked data.

After each auto-transplantation, the golden standard of the surgical protocol imposes the use of post-surgical sutures for stabilization and adaptation of soft tissue around the transplant. The goal is the same even though the suturing methods differ depending on the clinical case, such as using
simple interrupted or criss-cross pattern while using resorbable 3-0 polyglycolic acid sutures or Ethicon Vicryl 3-0. Besides, in some studies more stabilization was necessary to ensure the success of the post-surgical outcome, hence the use of splinting (semi-rigid stainless-steel splint, flexible composite resin-wire splint) (12 studies), while some articles lacked reporting these details. Surgical procedures usually demand some pharmaceutical coverage as mentioned in some studies reporting that antibiotics were administered post-surgically (13 studies), or even provided as a prophylaxis pre-operatively (6 studies), naming: Amoxicillin/Clavulanic acid, 500/125 mg; Doxycycline 100 mg; Phenoxy methyl-Penicillin 2g; Penicillin (2- 5 000 000 units). The next post-operative step was the endodontic treatment which was deemed necessary in 10 studies (NB! case reports reporting pre-operative endodontic treatment for auto-transplanted teeth were excluded from this systematic review); while the periodontal treatment was reported only in 4 studies. Analyzing the timing of orthodontic treatment, 2 following phases were sorted out: pre-surgical phase to make space for future auto-transplant (4 studies) or tooth alignment (2 studies) and post-surgical phase to make a proper tooth alignment. Different orthodontic appliances were used for different periods of time depending on the individual clinical case. Finally, the prosthodontic treatment was carried out on patients in 17 studies, in which composite resin build-ups were the most prevalent, whereas crowns or no treatment at all were also chosen alternative.
DISCUSSION

The clinical data collected in this systematic review illustrate that permanent tooth auto-transplantation should be considered as a treatment option based on its very high survival rate gravitating around 100% and success rate varying from 60 - 100%. This big range in success rate in this paper can be explained by its direct and indirect relation to different prognostic key factors. Starting with patient’s age which has been reported to influence significantly the periodontal ligament’s width which gets narrower with age. It has been documented to be 0.21mm in 11-16 years-age group and shrinking down to 0.15mm wide in 51-67 years-age group making it a risk factor with a big impact on teeth auto-transplantation success rate. Another main key factor is the stage of root development according Moorrees et al. (1963) modified by Kristerson (1985). The highest success rate is when the stage at the time of surgery is between 3rd and 4th which coincides with ½ to ¾ of root length. Many studies arguably agreed upon that immature teeth in early stages of development show less post-transplantation root growth relatively to the immature ones with more developed roots. In other words, a tooth with ½ root length has higher risk of arrested root development than the one ¾ root length, taking into consideration the intact Hertwig’s epithelial sheath around the apices.

However, incomplete root formation especially between stage lesser than 4th have up to 96% of pulp healing compared to 15% in stages 5-6th. This brings us to a widely-accepted concept since arrested root development is a possible risk, then it has been agreed on that the most optimal stage would be around the 4th, in such manner we provide proper future anchorage and higher chances of pulp healing for a better longevity of the transplant.

When speaking about root development stage, the apical width imposes itself which is of a vital importance since an apex width along with other factors can determine the occurrence of either pulp healing or necrosis. Any lesser width than 1mm would cause pulp necrosis which is assumed if no positive vitality test is achieved after 6-12 months post-operatively, if no pulp obliteration is seen, or if radiographic pathologies are diagnosed.

Another determining factor is type of donor tooth in relation to its future recipient site. In this paper, the premolars (85% of all transplants) are by far the widely auto-transplanted teeth into either another premolar site (44%) or into maxillary incisors (42%). This means that it is important for donor transplant to match as much as possible the recipient site dimensions. Since a converging multi-rooted or atypical root morphological tooth is considered a risk factor associated with surgical traumatic extraction to Hertwig’s epithelial sheath at the donor site as well as extensive recipient site preparation compromising bone volume to accommodate the complicated root morphology.
This in its turn will lead to a poor and unpredictable prognosis of future root development opting for an early loss of the transplant ⁵⁰.

Adding to the equation another prognostic factor, which is extra-oral storage of the freshly extracted donor tooth which varies from leaving the extracted transplant in its socket while preparing the recipient site ¹⁵, ¹⁶, ¹⁹, ²¹, ²³, ²⁴, ²⁹, ³¹, ⁴⁰ or placing it into a physiological media ¹⁸, ²⁴, ²⁶, ²⁷, ⁴². This factor is crucial especially if the roots are completely developed increasing pulp necrosis risk and decreasing periodontal cell vitality ⁵¹, ⁵². Fortunately, to eliminate the extra-oral time and storage risk factors, many methods has been developed including the use of CBCT to 3-Dimentional scan both the donor tooth candidate and its future recipient site ⁵³. Allowing surgeons to use an identical replica of the transplant to prepare accurately the recipient site before even extracting the transplant as well as less manipulation to donor tooth to preserve PDL by avoiding several trials of “try-in” the transplant into its future socket ³-⁶, ²⁵, ⁵³, ⁵⁴.

CBCT radiations in pediatric patient is controversial that is why recent innovation in radiology achieved a considerable reduction in the pediatric effective dose while maintaining sufficient image quality for tooth auto-transplantation planning and following up using the dose optimization protocols ⁵⁵.

After auto-transplantation, different suturing materials and techniques has been used depending on the clinical case itself, however the golden standard states that suturing the gingival flap around the neck of transplant is mandatory to provide a water tight fit that enhances healing, gingival re-attachment, and reduce bacterial invasion ⁴⁸. Besides, in most studies splinting has been carried out post-operatively for optimum stabilization. Even though different materials and methods has been used according the case, the principle is the same as to stabilize transplant within its new socket. The crucial detail in splinting is no occlusion interference should be present between the graft and its antagonists, in such way enhancing the healing of periodontal ligaments as the root development continues the transplant will erupt into proper position either spontaneously of assisted orthodontically ⁴⁸. Since a relation between transplant position and subsequent pulp healing is strong with 91% and only 56% pulp healing infra-occlusally and occlusally respectively ³-⁶. The timing and the type of movement generated by orthodontic forces is also crucial to prevent alteration of the root development/healing ⁷. A study shows that the recommended timing to start orthodontic movement is after the healing of periodontal ligament and before pulp obliteration and complete healing of bone, providing us with a window of 3-9 months post-operatively ⁴⁹.

After auto-transplantation, most cases healed uneventfully but some developed complications,
hence the endodontic therapy if pulp pathologies occurred\textsuperscript{20, 22-25}. Periodontal treatment was quite
seldom but always recommended as dressing against infections\textsuperscript{18}. However, orthodontic treatment
was always required and placed an important role both pre-operatively by creating enough mesio-
distal space to accommodate future transplant and post-operatively to provide stabilization, to bring
auto-transplanted tooth into normal occlusion and to align teeth within dental arch\textsuperscript{20-22, 28, 29, 35, 36, 42}.
Moreover, prosthodontic treatment was also very common since the transplant is often grafted in
esthetic region, so achieving red esthetics solely were not enough but also white esthetics were
often requested by patients, hence the composite build-ups or indirect restoration were carried out to
match the adjacent dentition\textsuperscript{19, 22-26, 28-36, 40}. Last but not least, depending on the country, antibiotic
therapy was requested as prophylaxis while in other countries they were under strict control as a
strategy against antibiotic resistance bacteria\textsuperscript{56}.

Hence, the aim and objective of this systematic review is to deduce if permanent tooth auto-
transplantation can be considered as predictable treatment alternative, by analyzing recent clinical
reports in order to compare different clinical factors that might alter or enhance success and survival
rates of this procedure. Simultaneously, a brief comparison with other standard treatments was
drawn to appreciate the uniqueness of teeth auto-transplantation in pediatric patients.

After discussing the influence of different clinical prognostic factors that affect the
high success and survival rates of the permanent tooth auto-transplantation, any practitioner would
appreciate how detailed the procedure is laid out for any surgeon to perform and get a predictable
outcome. But, it is still unfortunately not yet accepted as a reliable treatment option for replacement
of missing teeth in pediatric patients, and even less in adults\textsuperscript{57}. Hence, among the objectives of this
paper is to appreciate what this treatment can offer when none of orthodontic, prosthodontic, or
implant treatments can fulfill. Speaking about appreciation, as practitioners treating pediatric
patients on daily basis, know that a proper treatment plan is based on both the status of the oral
cavity as well as on the skeletal growth of the concerned child. This being said, a brief comparison
should be made between teeth auto-transplantation and other well-known reliable treatment options
to treat for example a 10 years old child whose one or both upper central incisors are lost/missing.
This case is extremely challenging taking into consideration several key factors: ongoing skeletal
growth pattern, number and type of missing teeth, etiology of tooth loss, and high esthetic demands.

Starting with orthodontic treatment in form of orthodontic space closure by mesialization and
aligning lateral incisor into the central incisor space which might be reasonable treatment plan.
However, it is very long and complex treatment especially in mixed dentition, facing many
challenges for instance risk of relapsing because unilateral space closure, increased load on the
lateral incisor’s PDL especially after delivering a larger crown with central incisor’s dimensions 58.

A second alternative is prosthodontic treatment which provides us with 3 options, the first one is removable partial denture which is the easiest, quickest and the most conservative by replacing the missing central incisor/s and functioning as space maintainer until skeletal growth is reached to deliver implants. However, any edentulous space lacking a functional matrix (tooth) will undergo resorption 59. A second option is fixed partial denture (FPDs), reported in a study of a 10 years follow-up the probability of survival for fixed partial dentures was 89.1% while the probability of success was 71.1%. Fixed bridges have been reported to have a 10-year survival rate of 80–85%, decreasing to 65% at 25 years 60. Lastly, the third option is resin bonded bridge (RBBs), which has been covered nicely by Bjarni E. Pjetursson in 2008 61 about the survival and complication rates of RBBs after follow up period of >5 years. Complications were in form of debonding, secondary caries on abutments and RBBs loss due to periodontitis which decreases the survival rate to 87.7% after 5 years. Even though the prosthodontic treatment provides us with more options, yet none of them has a stimulating effect on the edentulous/residual ridge to prevent it from resorption and thus soft tissue collapse and loss of papilla. Not only this, but compromising healthy adjacent teeth for preparation is a major drawback.

Last but not least, implant treatment which is the most popular and over-rated treatment option. In a very unique study by Paweł P. in 2016 62 on a patient who has a bilateral agenesis of #22 and #12, has been treated with both auto-transplantation of #18 to replace #12 and implant to replace #22. After 9 years follow-up the results showed that auto-transplantation provided a positive and uneventful outcome covering physiological mobility, proper sulcus depth, stimulating new bone formation around the transplanted #18, continued eruption in harmonious way with adjacent teeth, and satisfactory esthetics after delivering a ceramic crown in shape of #12. Meanwhile, the implant replacing #22 didn’t fulfill all the outcomes previously mentioned, leading to infra-position of #22, labial and marginal bone loss at neighboring teeth causing labial mucosal discoloration.

Even biologically speaking, a bacterial sampling showed more bacteria found at the implant site compared to the auto-transplanted tooth site 63. Other studies covered more complications such as implant, screw or abutment fracture as well as peri-implantitis causing bone loss more than 2mm over 5 years follow-up 64. On top of this, recent studies documented those teeth auto-transplantation has reached a success rate equal to endosseous dental implants with 90% success rate in a mean of 26 years follow-up 13, 65.

To sum-up, permanent tooth auto-transplantation is a very technique-sensitive treatment, and even if its success and survival rates are very high competing with mostly used treatments out there, it
doesn’t mean that its post-operative phase will be uneventful especially after a long follow-up period which in this systematic review stretched up to 21 years. The real challenge is to early diagnose the complication and to be able to tell whether it was the causative factor the auto-transplantation itself or the following treatments such as orthodontic movement or prosthodontic restoration. As unique as it sounds, even after encountering a failure, the auto-transplanted tooth can function as a temporary measure preserving the alveolar bone and soft tissues dimensions from collapsing, simplifying a future implant placement once the pediatric patient has reached proper age indicated for implant.

Unfortunately, the controversial debate about permanent tooth auto-transplantation is ongoing, hence the objective of this paper clarifying and simplifying the ambiguities concerning this treatment. However, during the making of this systematic review many limitations has be encountered, naming mainly the lack of access to very interesting articles only if purchased, weak methodological and non-standardized studies to allow carrying out a meta-analysis, studies with small samples or with insufficient follow-up periods, and 5-10 years’ interval restriction by master thesis regulations which led to exclude big studies with long follow-up periods, concrete results, and good critics to the tooth auto-transplantation as a treatment plan for pediatric patients. This might have influenced the core and the outcome of this systematic review to a certain extent.
Yet, despite the controversy concerning the permanent tooth auto-transplantation, its continuous development involving both solid clinical and theoretical research showed its fruitful results. Providing us with an overall high success and survival rates reaching values (>90%) as good as the ones for endosseous dental implant during a long follow-up period. And even during an encountered failure, auto-transplant could be temporary solution preserving bone and soft tissue bulk in aesthetic zone for future easy implant placement once indicated. This proves how well studied and planned this treatment is, starting from patient’s case selection until post-operative therapy. Thus, encouraging practitioners implement this treatment in their option-list as a predictable alternative while assessing any pediatric patient with missing permanent teeth that need to be replaced.

On the other hand, with regards to adverse outcomes and complications associated with this therapy such as arrested root development, ankylosis, pulp necrosis, and peri-apical lesions, it could be concluded that these events are directly dependent on some risk factors mainly root developmental stage, apical width, extra-oral storage and time, orthodontic movement, as well as transplant placement post-surgically in relation to the occlusion.

Finally, more attention should be paid into the making of clinical trials with strong methodologic protocol, big samples, long follow-up period, and low risk of bias. In such way, a concrete and solid conclusion can be established to re-fine the concept of the permanent tooth auto-transplantation in pediatrics as a treatment option.
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### Permanent tooth auto-transplantation in pediatrics as treatment option: a systematic review

#### INTRODUCTION

**Rationale**

Objectives/aim

Aim and objective is to review whether permanent tooth auto-transplantation can be considered as predictable treatment alternative in pediatric patients who lost/miss permanent tooth. By implementing the following tasks:

- Analyzing recent clinical data and discussing different clinical key factors that might alter or enhance success and survival rates of this treatment.
- Drawing a brief comparison with other standard treatments carried out in pediatrics to appreciate the uniqueness of teeth auto-transplantation.
- Deducing if this treatment can be considered as predictable treatment alternative in pediatrics.

#### METHODS

**Eligibility criteria**

- **PICOS**:
  - **P**- Participants: < 18 years; indicated (trauma, loss/absence of tooth, un-restorable tooth, etc) for auto-transplantation; other treatments (orthodontic, prosthodontic) are deemed unfavorable, presence of donor tooth,
  - **I**- Intervention: tooth auto-transplantation intervention;
  - **C**- Conventional and modified (CBCT surgical planning and transfer via stereolithographic tooth replica with surgical guide) surgical methods;
  - **O**- Success / Survival rate outcomes;
  - **S**- Study design selection: clinical trials and case reports

  **Inclusion criteria:**
  - Follow-up period >0.5 year.
  - Report characteristics: newer than 2007 (10 last year);
  - English language;
  - Full texts.
  - Study design: clinical case report; clinical trials;
  - Studies performed in vivo and on humans

  **Exclusion criteria:**
  - Non-full articles or inaccessible full articles unless purchased
  - Study design: systematic reviews
  - Studies mixing both children and adults, including only adults.
  - Lack of important data: follow-up period, root developmental stage, surgical protocol.
  - Studies using other methods for auto-transplantations (ex. cryo-preservation)
  - Studies in vitro, on animals, non-english, follow-up period < 0.5 years.
  - Studies in which traumatic teeth were treated endodontically prior auto-transplantation was planned.

**Information sources**

- Electronic databases: Pubmed, ReasearchGate, Wiley Online Library.
- Key words: dental/tooth, auto-transplantation/ autogenous transplantation; pediatric/child.
- Time frame: June 2017 – December 2017

**Study selection**

- Identification phase by entering the key words in different combinations and according including criteria.
- Screening excluding duplicates;
- Eligibility according exclusion criteria: non-full texts, other study designs, articles about adult and pediatric patients, lack of relevant details.
- Double-checking articles that we included in systematic review by supervisor (Sandra Žemgulytė).

**Outcomes and prioritization**

- Assessing success and survival rates in relation to different prognostic factors (root stage development, tooth’s root morphology, surgical protocol, etc).

**Risk of bias in individual studies**

- No risk of bias in 19 case reports
- Some of the 8 clinical trials have a significant risk of bias.

**Risk of bias across studies**

- No tool was used for assessing risk of bias in this systematic review.
### Table 1. Auto-transplantation types, definition, indications, protocol, and success criteria.

<table>
<thead>
<tr>
<th>Type of auto-transplantation</th>
<th>Definition</th>
<th>Indications of selection for type of autoTX</th>
<th>Brief surgical protocol</th>
<th>Success criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional</strong>&lt;br&gt;15, 17, 20-34, 36-41</td>
<td>Moving tooth surgically from one socket to another in the same individual. <strong>Two types</strong>:&lt;br&gt;<strong>One-staged</strong>: recipient site is prepared immediately prior transplantation. <strong>Two-staged</strong>: recipient site is prepared and left to heal for 7 days prior.</td>
<td>• Young patients who didn’t reach growth spur yet. • Teeth: missing teeth, with hopeless prognosis, abnormal morphology. • Appropriate donor tooth can be used without any negative effects from its loss from its position in the arch. • Good candidate donor teeth with: simple root form, optimal stage of root development, easy extraction, and of sizes matching for recipient site.</td>
<td>• Extraction of damaged tooth in the recipient site. • Extraction of donor tooth and store it (in its original socket, physiological solution) • Preparation of recipient site according to transplant. • Transplant into the recipient socket • Tight suturing of transplant. • Splinting if needed.</td>
<td>• Tooth still present at recall, • Pain-free. • No percussion sensitivity. • Positive cold test, 6m post-surg. • Normal chewing. • Grade I tooth mobility, 4w post-surg. • X-ray: o Continuous root development o Crown:root ratio &lt;1. o Normal lamina dura o Pulp canal obliteration o No progressive root resorption o No pathologies 6-9m post-surg: ankylosis, any type of root resorption. o New bone regeneration around transplant. o Normal healing of recipient alveolus, 3 m post-surg. o New bone regeneration around transplant. o Normal periodontal tissues: depth of sulcus&lt;3mm, gingival contour, and gingival color.</td>
</tr>
<tr>
<td><strong>Trans-alveolar</strong>&lt;br&gt;30,35</td>
<td>Surgical extraction of a severely impacted tooth, and re-positioning it into its normal socket within the arch and in proper occlusion. The socket is usually surgically prepared.</td>
<td>• Young patients who didn’t reach growth spur yet. • Severe impacted tooth, due to: retained primary tooth, crowding, trans-migration, etc. • Proper mesio-distal space to accommodate the transplant, usually made by orthodontic treatment prior to surgery.</td>
<td>• Extraction of impacted transplant. • Preparation of recipient socket according to transplant. • Try-in of transplant • Tight suturing of transplant. • Splinting if needed.</td>
<td>Similar to conventional.</td>
</tr>
<tr>
<td><strong>Intra-alveolar</strong>&lt;br&gt;18, 19</td>
<td>Surgical intervention to move teeth within its original socket: surgical extrusion/rotation/and/or up-righting.</td>
<td>• Jeopardized biologic width due to deep caries. • Fractures or root resorption. • When teeth have erupted in tilted direction and there are more advantages in up-righting them surgically than orthodontically.</td>
<td>• Extraction of the transplant. • Preparing of socket • Re-plantation of transplant • Tight suturing. • Splinting.</td>
<td>Similar to conventional.</td>
</tr>
<tr>
<td><strong>Intentional replantation</strong>&lt;br&gt;42</td>
<td>Surgical procedure to solve any trauma (avulsion) or an endodontic problem that cannot be solved by either a conventional non-surgical or surgical endodontic approach: we extract the tooth, treat it endodontically and re-implant it into its original socket.</td>
<td>• Contra-indication of endodontic treatment either conventional or micro-surgical. • Teeth with single, convex and conical-shape root. • Easily and atraumatic tooth extraction.</td>
<td>• Extraction of tooth • Cutting off 3mm of apex; • Retro-filling of root canal extra-orally; • Replanting tooth into its original socket without changing its position.</td>
<td>Similar to conventional. • Healing of the peri-apical lesion.</td>
</tr>
</tbody>
</table>
Table 2. Characteristics of the studies.

<table>
<thead>
<tr>
<th>Researcher/author</th>
<th>Study design</th>
<th>N. of patients</th>
<th>Age range</th>
<th>N. of teeth</th>
<th>Transplanted (donor) tooth</th>
<th>AT. (recipient) site</th>
<th>Root development stage*</th>
<th>Reason/etiology of AT.</th>
<th>Follow up period</th>
<th>Complications</th>
<th>Success rate</th>
<th>Survival rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rafael Lima Verde Osterne (2015)</td>
<td>CR</td>
<td>1</td>
<td>14 y</td>
<td>3</td>
<td>#38 #48 #28</td>
<td>#36 #35 #33</td>
<td>2nd – 3rd</td>
<td>Ameloblastoma</td>
<td>2-4 y</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Paweł Plakwicz (2014)</td>
<td>CR</td>
<td>9</td>
<td>11.4 – 17 y</td>
<td>9</td>
<td>P1, P2, P3, P6: #45 P2, P3: #25 P1, P5: #15 P5: #35</td>
<td>#45</td>
<td>3.66th ± 1.22 and 5th ± 1.41</td>
<td>Severe impaction (angulation 90-180°).</td>
<td>2 – 8.5y</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>R. Ebru Tirali (2013)</td>
<td>CR</td>
<td>1</td>
<td>10 y</td>
<td>1</td>
<td>#21 (super-numerary)</td>
<td>#11</td>
<td>&gt;5th</td>
<td>#11 abnormal morphology (fusion).</td>
<td>2y.</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Divya S Sharma (2012)</td>
<td>CR</td>
<td>1</td>
<td>10 y</td>
<td>1</td>
<td>#25</td>
<td>#25</td>
<td>3rd – 4th</td>
<td>Severe impaction (angulation 90-180°).</td>
<td>1.5y</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Kotaro Tanimoto (2010)</td>
<td>CR</td>
<td>2</td>
<td>4.7-9.3y</td>
<td>2</td>
<td>P1: #14 P2: #34</td>
<td>#25 #22</td>
<td>-</td>
<td>Cleft lip &amp; palate with congenital absence of tooth.</td>
<td>2-2.8 y</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Author</td>
<td>Year</td>
<td>CR/CT</td>
<td>Age Range</td>
<td>Methods</td>
<td>Outcomes</td>
<td>Follow-Up</td>
<td>Treatment</td>
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</tr>
<tr>
<td>Dror Aizenbud</td>
<td>2012</td>
<td>CR</td>
<td>6.8-11y</td>
<td>#35, #45</td>
<td>CLP with congenital absence of tooth.</td>
<td>1-4y</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Tadasu Tanaka</td>
<td>2008</td>
<td>CT</td>
<td>9.7-16y</td>
<td>#35, #45</td>
<td>Congenital absence of tooth</td>
<td>4-15y</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Marjolijn Gilijamse</td>
<td>2016</td>
<td>CT</td>
<td>9-18y</td>
<td>#35, #45</td>
<td>Trauma 78%, Agenesis 9%, Development disturbances 6%.</td>
<td>0.8-5y</td>
<td>Pulp necrosis &amp; arrested root growth 3.3%.</td>
<td>96.6%</td>
<td>100%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Inessa Michl</td>
<td>2017</td>
<td>CT</td>
<td>11-19y</td>
<td>#35, #45</td>
<td>Trauma 62% Aplasia 38%</td>
<td>0.8-5y</td>
<td>Root resorption 30.8%</td>
<td>73%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maryam Shahbazian</td>
<td>2013</td>
<td>CT</td>
<td>9-18y</td>
<td>#35, #45</td>
<td>Congenital absence of tooth</td>
<td>1y</td>
<td>1st gr: 2 resorptions, 4 ankyloses (2 tooth loss) 2nd gr: 1 resorption, 1 ankylosis</td>
<td>86.9%</td>
<td>95.8%</td>
<td></td>
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</tr>
<tr>
<td>Pawel Plakwicz</td>
<td>2013</td>
<td>CT</td>
<td>9.8-17y</td>
<td>#35, #45</td>
<td>Congenital absence of tooth</td>
<td>0.5-6.5y</td>
<td>1 ankylosis 1 unfavorable crown-to-root ratio.</td>
<td>91.3%</td>
<td>100%</td>
<td></td>
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</tr>
<tr>
<td>Verweij JP. (2015)</td>
<td></td>
<td>CT</td>
<td>12.3-18.4y</td>
<td>#35, #45</td>
<td>Trauma 21%</td>
<td>1.6-2y</td>
<td>8 Endo pathology. 7 ankyloses 2 root resorption. 1 perio pathology 1 loss of suture 1 high mobility</td>
<td>82%</td>
<td>100%</td>
<td></td>
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</tr>
<tr>
<td>Anne-Lise Maseng Aas</td>
<td>2011</td>
<td>CR</td>
<td>9 y</td>
<td>#35, #45</td>
<td>Trauma: #11, 21, Necrosis: #14</td>
<td>21y</td>
<td>None</td>
<td>100%</td>
<td>100%</td>
<td></td>
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</tr>
<tr>
<td>A. Mendoza-Mendoza.</td>
<td>2011</td>
<td>CT</td>
<td>9-13y</td>
<td>#35, #45</td>
<td>Trauma</td>
<td>10-14y</td>
<td>1 Surface resorption → extraction. 1 Inflammatory resorption → extraction</td>
<td>80%</td>
<td>100%</td>
<td></td>
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<tr>
<td>J.A. Díaz (2014)</td>
<td></td>
<td>CT</td>
<td>7-19y</td>
<td>#35, #45</td>
<td>Trauma 66.7% Congenital absence of teeth 22.2% Caries 8.3%</td>
<td>1.2-8y</td>
<td>Arrest of root growth 40%. Replacement resorption 11%. Severe external inflammatory resorption 2.7%, Endo-periodontal infection 2.7%, Pulp necrosis 2.7%,</td>
<td>83.3%</td>
<td>97.2%</td>
<td></td>
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</tr>
<tr>
<td>Name</td>
<td>Specialty</td>
<td>Age</td>
<td>Stage</td>
<td>#</td>
<td>Description</td>
<td>Length</td>
<td>Cause</td>
<td>Recovery Rate</td>
<td></td>
<td></td>
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<tr>
<td>Lisa Alice Hwang (2017)</td>
<td>CR</td>
<td>14</td>
<td>y</td>
<td>3</td>
<td>#21 #22 #23 → #21 - → #22 &gt;5th Odontoma associated impaction</td>
<td>1.2y</td>
<td>5th</td>
<td>&gt;90%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Juliana Paiva Marques Lima (2009)</td>
<td>CR</td>
<td>11</td>
<td>y</td>
<td>2</td>
<td>2 PrM 2 U.C.I. 3rd–4th Trauma</td>
<td>5y</td>
<td>None</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tatjana Nimcenko (2014)</td>
<td>CR</td>
<td>15-18y</td>
<td>15</td>
<td>1</td>
<td>1 #18 4 #28 4 #38 6 #48 → 1 #46 2 #26 6 #36 6 #46 3rd–4th Severe caries destruction, Tooth fracture Inadequate endodontics Apical periodontitis</td>
<td>0.5-0.8y</td>
<td>2 failures: Loss of initial suture → tooth loss. Persisting apical lesion at recipient site.</td>
<td>87%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Jaime Andre`s Diaz (2008)</td>
<td>CT</td>
<td>7-12y</td>
<td>10</td>
<td>4</td>
<td>4 #34 3 #45 2 #44 1 #35 → 6 #21 4 #11 3rd–4th Trauma</td>
<td>0.5-2.3y</td>
<td>60%</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Pawel Plakwicz (2013)</td>
<td>CR</td>
<td>9</td>
<td>y</td>
<td>2</td>
<td>#33 #43 → 3rd–4th Severe impaction</td>
<td>5y</td>
<td>None</td>
<td>100%</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Eloa R. Luvizuto (2013)</td>
<td>CR</td>
<td>10</td>
<td>y</td>
<td>1</td>
<td>#34 or 35 → 21 3rd–4th UCLP with Congenital absence of tooth.</td>
<td>5y</td>
<td>None</td>
<td>&lt;100%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>J. P. Verweij (2017)</td>
<td>CR</td>
<td>18</td>
<td>y</td>
<td>3</td>
<td>#18 #38 #48 → #14 #36 #37 ≈ 4th Trauma</td>
<td>0.5y</td>
<td>None</td>
<td>100%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>George D. Strbac, (2016)</td>
<td>CR</td>
<td>11</td>
<td>y</td>
<td>2</td>
<td>#35 #45 → #11 #21 3rd–4th and 4th Trauma</td>
<td>1y</td>
<td>None</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Mendoza Mendoza (2010)</td>
<td>CR</td>
<td>10</td>
<td>y</td>
<td>1</td>
<td>#44 → 11 3rd Trauma</td>
<td>14y</td>
<td>None</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Davidovich (2008)</td>
<td>CR</td>
<td>6</td>
<td>y</td>
<td>1</td>
<td>#21 → 21 3rd–4th Avulsion (extra alveolar time&lt;60min)</td>
<td>3y</td>
<td>None</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 3. Auto-transplantation’s different treatment phases.

<table>
<thead>
<tr>
<th>Researcher/author</th>
<th>Surgical part</th>
<th>Technique of AT.</th>
<th>Extra-alv. time</th>
<th>Storage media</th>
<th>Suture</th>
<th>Splint Type*</th>
<th>Splint period</th>
<th>Perio treatment</th>
<th>Endo treatment</th>
<th>Ortho treatment</th>
<th>Prosthodontic treatment</th>
<th>Antibiotic treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paweł Plakwicz &amp; Ewa Monika Czochrowska (2014)</td>
<td>Intra-alv.</td>
<td>&lt; 7min.</td>
<td>Saline</td>
<td>Post-surgery</td>
<td>Flexible 0.35mm wire-composite</td>
<td>2w</td>
<td>-</td>
<td>-</td>
<td>Make space for transplants</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>R. Ebru Tirali (2013)</td>
<td></td>
<td>Conv.</td>
<td>Straight in recipient.</td>
<td>None</td>
<td>Post-surgery</td>
<td>Semi-rigid wire-composite</td>
<td>2w</td>
<td>-</td>
<td>-</td>
<td>3m after healing, ortho wire.</td>
<td>-</td>
<td>Post-surgery: Amoxicillin 20 mg/kg 2x/d. For 1w.</td>
</tr>
<tr>
<td>Kotaro Tanimoto. (2010)</td>
<td>Conv. (after iliac bone graft)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Post-surgery: &lt;2w.</td>
<td>-</td>
<td>-</td>
<td>P1, P2: multi-bracket appliances tooth alignment, (P1 for 10m.)</td>
<td>P1: tooth alignment again, after 15d, for 33m. P2: tooth alignment again, after 10m, for 24m.</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Author</td>
<td>Year</td>
<td>Conversion Method</td>
<td>Donor Bone Graft</td>
<td>Donor Socket Time</td>
<td>Donor Site Sutures</td>
<td>Post-surgery Antibiotics</td>
<td>Ortho Treatment</td>
<td>Ortho Integration</td>
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<tr>
<td>Dror Aizenbud</td>
<td>2013</td>
<td>Conv. (after iliac bone graft)</td>
<td>None</td>
<td>Straight in recipient.</td>
<td>Suture (silk)</td>
<td>P1-4: Active ortho treatment, after 6m.</td>
<td>-</td>
<td>-</td>
<td></td>
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</tr>
<tr>
<td>Tadasu Tanaka</td>
<td>2008</td>
<td>Conv. (1 stage method)</td>
<td>Kept in donor socket &lt;10min</td>
<td>-</td>
<td>-</td>
<td>Post-surgery: 40%. &lt;2y.</td>
<td>Correction of transplants rotation, 1m later. Edgewise appliance therapy with a 0.018 pre-torqued bracket, involving a sequence of Niti leveling arch wires and completed with a 0.017 0.025 finishing ideal arch wire, for 45m.</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Marjolijn Gilijamse</td>
<td>2016</td>
<td>Conv.</td>
<td>Straight in recipient.</td>
<td>None</td>
<td>Resorbable 3-0 polyglycolic acid sutures.</td>
<td>4 teeth: Rigid wire-composite</td>
<td>Post-surgery: 1.6%. &lt;12m.</td>
<td>Ortho after healing of surgical site.</td>
<td>Resin-based composite on labial sides. At adulthood: crowns.</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inessa Michl</td>
<td>2017</td>
<td>Conv.</td>
<td>6x: Straight in recipient. 20x: 1-14min</td>
<td>6x None 20x stored in 100 mg doxycycline, 4 mg dexamethasone, &amp; 10 ml saline</td>
<td>20 teeth: wire (titanium)-composite. 1 tooth: Suture</td>
<td>Post-surgery: 30.7%.</td>
<td>For 5t.: attached to orthodontic labial bar with composite adhesive. Ortho integration of the transplant into the pre-existing multi-bracket appliance.</td>
<td>After ortho: 38% (10 teeth)</td>
<td>Post-surgery: Amoxicillin 50mg/kg per day. For 7d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maryam Shahbazian</td>
<td>2013</td>
<td>1st. gr: Conv. w/o stereo-lithographic surgical guide. 1st. gr: Without S.S.G: 3-10min.</td>
<td>-</td>
<td>Flexible wire-composite</td>
<td>Post-surgery: 9 teeth. &lt;1y</td>
<td>-</td>
<td>Composite buildup</td>
<td>Post-surgery: Antibiotic. For 7d.</td>
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<td>Study</td>
<td>Patient Information</td>
<td>Procedure</td>
<td>Time</td>
<td>Grafting Material</td>
<td>Suture Type</td>
<td>Time</td>
<td>Post-Surgery Treatment</td>
<td>Notes</td>
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<td>Pawel Plakwicz</td>
<td>Conv. 79% Trans-alv. 21%</td>
<td>2nd gr.: CBCT surgical planning and transfer via stereolithographic tooth replica with surgical guide</td>
<td>&lt;15min.</td>
<td>Saline</td>
<td>Criss-cross sutures over the premolar's cusps, for 2w.</td>
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<td>For 4t.: bonded with ortho brackets.</td>
<td>Post-surgery: 1-2y 3 teeth: Composite build-up.</td>
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<td>Verweij JP. (2015)</td>
<td>Conv.</td>
<td>-</td>
<td>Saline</td>
<td>-</td>
<td>Suture (3-0 Vicryl rapide)</td>
<td>-</td>
<td>Post-surgery: 5.4%, &lt;23.5m.</td>
<td>1 Molar</td>
<td>-</td>
<td>Pre-surgery: prophylaxis amoxicillin/clavu-lanic acid, 500/125 mg. For 7d.</td>
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<td>Anne-Lise Maseng Aas (2011)</td>
<td>Conv.</td>
<td>-</td>
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<td>#13 mesialization to replace the #12. Ortho &lt;12y.o.</td>
<td>Post-surgery: 4m. composite buildups. Crowns at 20 y.o.</td>
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<td>Author</td>
<td>Case Description</td>
<td>Treatment Details</td>
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<tr>
<td>A. Mendoza-Mendoza (2011)</td>
<td>Conv. Straight in recipient. None 2 stitches crossed labio-lingually, with 3-0 suture silk. For 1w.</td>
<td>6m later, ortho: 0.018 pre-torqued brackets with a sequence of NiTi levelling arch wires &amp; completed with a 0.017 · 0.025-inch finishing arch-wire. For 32 ± 6m.</td>
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<td>J.A. Díaz (2014)</td>
<td>Trans-alv. Conv. - Flexible with Composite 1-13w Post-surgery: 11.11%. post-prostho: 22.22% &lt;4-10m. 1 tooth: root scaling and sealing of the resorptio defect with GIC.</td>
<td>Composite buildups Pre-surgical: amoxicillin or doxycyclic prescribed according to patient’s age.</td>
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<td>Lisa Alice Hwang (2017)</td>
<td>Trans-alv. #21 Conv. #23 + Autograft. Suture interrupted Semi-rigid Wire (0.026mm)-Acrylic 2w Post-surgery: 2 weeks with Ca(OH)₂ Dressing.</td>
<td>Diastema closed with composite resin.</td>
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<td>Juliana Paiva M. L. 2009</td>
<td>Conv. - - - - - - - - - - - - - - Ortho after prosth treatment</td>
<td>Composite buildups</td>
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<td>Tatjana Nimcenko 2014</td>
<td>Conv.: (if periapical lesion in recipient site➔AT after 2-4w of X). Kept in donor socket. Criss-cross sutures, for 2w. Rigid Composite 4w</td>
<td>Post-surgery. Temporal bite raise on adjacent teeth, for 1m. Post-surgical: Amoxicilliu m (0.5 × 3/day).</td>
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<td>Author</td>
<td>Technique</td>
<td>Pre-surgery</td>
<td>Surgery</td>
<td>Post-surgery</td>
<td>Notes</td>
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<td>Jaime Andre’s Diaz 2008</td>
<td>Conv.</td>
<td>1-5 min</td>
<td>-</td>
<td>-</td>
<td>Flexible with Composite 1-9w Post-surger: 40% &lt;6-9m. Post-protho: 40% 5 patients 5 patients. Composite buildups 3 crowns. Post-surgery: Amoxicillin 500 mg, 3x/d. For 7d.</td>
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<td>Pawel Plakwicz (2013)</td>
<td>Trans-alv.</td>
<td>10min</td>
<td>-</td>
<td>Suture for 9d.</td>
<td>Post-surgery: &lt;1y 4m later, transplants bonded to ortho brackets, for alignment and traction (for #33), for 5y. Post-surgery: Amoxicillin 500 mg every 8 hour. For 1 week.</td>
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<td>Eloa R. Luvizuto 2013</td>
<td>Conv. (6m after bone graft) (one stage method)</td>
<td>-</td>
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<td>-</td>
<td>Post-surgery: &lt;1y A semi-rigid splint was placed using orthodontic wire and brackets 1y later, ortho began to perform torsiversion of the transplant close diastema. Post-surgery: Amoxicillin 500 mg every 8 hour. For 1 week.</td>
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<td>Muhamad Abu-Hussein 2015</td>
<td>Conv.</td>
<td>-</td>
<td>-</td>
<td>Suture for 1-2w.</td>
<td>Post-surgery: &lt;1y A semi-rigid splint was placed using orthodontic wire and brackets 1y later, ortho began to perform torsiversion of the transplant close diastema. Post-surgery: Amoxicillin 500 mg every 8 hour. For 1 week.</td>
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<td>J.L. Jensen 2010</td>
<td>Conv.</td>
<td>-</td>
<td>-</td>
<td>Criss-cross suture</td>
<td>Post-surgery: &lt;1y A semi-rigid splint was placed using orthodontic wire and brackets 1y later, ortho began to perform torsiversion of the transplant close diastema. Post-surgery: Amoxicillin 500 mg every 8 hour. For 1 week.</td>
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<td>J. P. Verweij 2017</td>
<td>Conv. (CBCT donor replica)</td>
<td>1min 9s-1min 56s</td>
<td>-</td>
<td>Suture (Ethicon Vicryl 3-0)</td>
<td>Composite 1-9w Post-surgery: &lt;1y A semi-rigid splint was placed using orthodontic wire and brackets 1y later, ortho began to perform torsiversion of the transplant close diastema. Post-surgery: Amoxicillin 500 mg every 8 hour. For 1 week.</td>
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<td>Georg D. Strbac, 2016</td>
<td>Conv. (virtually planned 3D templates)</td>
<td>Straight in recipient site.</td>
<td>None</td>
<td>non-rigid suture fixation across the occlusal plane.</td>
<td>Post-surgery: 6m, CAD-CAM non-prep veneers. Post-surgery: Amoxicillin 500 mg, 3x/d. For 7d.</td>
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| A. Mendoza  
Mendoza 2010 | Conv. | Straight in recipient site. | None | Suture (3-0 silk) | 1w | - | - | - | - | Post-surgery: 6m, composite buildup. 14y, crowns for #11 & 21. |
| Esti Davidovich | Replantation | 10min | Saline | Suture gingival laceration | Semi-rigid Composite | 6w | - | - | - | Post-surgery: 1 year later mouth guard. 2 years later, ortho referral. |

Type* – Types of splints 67.