

# A prospective Saudi dental stem-cell bank from the perspective of the public and dental practitioners: A cross sectional survey

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## ABSTRACT

**Objectives:** The aim of this study (1) To evaluate the Saudi public's knowledge and attitude on dental stem cells (DSC) for therapeutic/banking purposes, (2) To evaluate the perception of Saudi dentists towards DSC and their attitude towards banking of DSC. **Methodology:** This was a cross-sectional study based on an electronic survey distributed through the social media nationwide among the Saudi public, and through paper-based surveys among dentists in Riyadh. By convenience, eligible study participants were Saudi adults from the community and dentists from 17 dental centers in different regions of Riyadh. Using SPSS v. 25, descriptive statistics (n,%; PMS  $\pm$  SD) and bivariate analyses (Pearson's Chi square, Mann Whitney) were conducted to determine factors associated with the study outcomes, with a *P* value statistically significant at  $<0.05$ . **Results:** For the Saudi public, 1494 participants completed the survey. The PMS  $\pm$  SD of public knowledge was  $25.5 \pm 25.9$ , while their attitude was  $80.2 \pm 27.0$ . Factors associated with higher knowledge scores were younger age groups, while female participants, older age groups, university educated and employed participants had higher attitude. For Saudi dentists, 246/262 (94%) dentists responded to the questionnaire. Their PMS  $\pm$  SD of perception towards DSC research for regenerative purposes was  $74.5 \pm 15.6$ . Factors associated with higher perception scores were those with more experience. Dentists who had higher perception scores towards DSCs were significantly more willing to save teeth for regenerative dental treatment. **Conclusion:** The Saudi public community had poor knowledge about the therapeutic and research benefits of DSC, yet high degree of attitude to enroll in a future Saudi DSC bank. Saudi dentists had moderately high levels of perception towards DSC research.

**Keywords:** Dental Pulp Stem cells, dental stem cell, stem cells banking, stem cells from human exfoliated teeth

## Introduction

Living in a world of modern medicine were new extraordinary advances rise every minute. Stem cell field has captured the attention of many researchers for so many years to achieve

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regenerative capacity to improve human survival outcomes. Stem cells have the potential to remain undifferentiated while going through multiple cycles of cell division. They can be either embryonic or adult (postnatal). Embryonic stem cells are derived from the blastocyst of a human embryo and differentiated to three primary germ layers: ectoderm, endoderm, and mesoderm. Adult stem cells, also known as somatic stem cells, are identified in various tissues throughout the human body such as bone marrow, adipose tissue, blood vessels, and dental tissue.<sup>[1]</sup>

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Stem cells harvesting and application in dentistry still triggers some controversy, due to lack of orientation, ethical issues and poor public knowledge.<sup>[2]</sup> Recent studies in the 2<sup>nd</sup> millennium have shown that stem cells can be obtained from human exfoliated deciduous teeth (SHED) which is a non-invasive and an easy approach of harvesting stem cells [Figure 1].<sup>[3]</sup> Deciduous teeth are naturally abandoned after teeth shedding. Instead, these stem cells can be collected, cultured, and eventually differentiated into odontoblasts, osteoblasts, chondrocytes, adipocytes, and neural cells to be used in the future.<sup>[4]</sup>

Dental Stem Cells (DSCs) obtained from tooth structure are adult stem cells and they can be used throughout the human body. Similarly, stem cells from extra-oral sites have the potential to regenerate dental tissue.<sup>[5]</sup> It has been reported that roots of teeth and periodontal ligaments were regenerated from DSCs.<sup>[6]</sup> These findings have been further strengthened by the generation of a small tooth from tooth buds which was transplanted *in vivo*.<sup>[7]</sup> Moreover, dental pulp stem cells (DPSCs) and dental follicle stem cells (DFSCs) related to wisdom teeth are being examined for possible dentine and enamel formation.<sup>[8,9]</sup> In the recent years, clinical studies have been carried out using stem cells for augmentation of alveolar ridge, generation of temporomandibular joint, and reconstruction of a resected mandible.<sup>[10-14]</sup>

The process of providing dental treatment using DSCs starts with the donor (public) who will donate or store his/her tooth, and the provider (dentist) who will collect DSCs from the patient and provide the treatment using stem cells. In Saudi Arabia, studies targeting stem cells in the field of dentistry are few, and none of them has addressed the public's willingness to donate or participate in a national bank for dental stem cells. Similarly, there are no studies in Saudi Arabia have explored the opinions of dental practitioners regarding the use of DSCs. Therefore, the aim of this study was both to evaluate the Saudi public's level of knowledge and attitude on dental stem cells for therapeutic/banking purposes, and to evaluate the perception of Saudi dentists towards dental stem cells and their attitude towards banking of dental stem cells.

## Methods

### Population and sampling

Approval from ethics committee was obtained, on 26 July 2018. This study targeted both the Saudi public and dental practitioners in July 2018. Participants were conveniently selected for this study. Social media networks are accessible to everyone nowadays, so it was used to reach people in a wider range all around Saudi Arabia. Eligible study participants were Saudi adults from the community nationwide. For the dentists, they were approached from 17 public and private dental centers in different regions of Riyadh. Eligible participants were dentists and dental interns living in Riyadh city.

### Data collection (Instrument)

Approved by King Abdullah International Medical Research Centre IRB (RSS18/020/R), this was a cross-sectional study. Data for the public was collected using an anonymous, electronic survey taken from a previously validated questionnaire about Public Awareness on Cord Blood Banking in Saudi Arabia (2018).<sup>[15]</sup> The questionnaire was translated to Arabic and modified according to this study. The survey had an explanatory letter and a consent to participate. Sample characteristics included sex, age, marital status, level of education, occupation, financial income, and coverage of dental expenses. The Saudi public knowledge about dental stem cells (correct vs. wrong statement) and attitude to donate tissues (negative vs. positive attitude) were evaluated based on four statements each. Their scores were summated and then presented in percentage mean scores  $\pm$  standard deviation (PMS  $\pm$  SD).

The self-administered questionnaire among dentists was developed from similar studies and reviewed by Institutional Review Board in KAIMRC.<sup>[16]</sup> In addition to the sample characteristics used in the public, it also included their dental specialty and work experience. The Saudi dentists' perception (nine statements), were rated (negative vs. positive) before being scored and presented as PMS  $\pm$  SD. Dentists' willing to attend training on regenerative stem cell therapies and their willing to save teeth/dental tissue were assessed (no vs. yes).

### Procedure

The research team which consisted of 4 senior dental students approached dentists from 17 dental centers in different regions of Riyadh. They explained the aim of the study and invited them to participate.

The public survey was distributed through social media using Twitter, WhatsApp, and similar social applications to reach people from all around the Kingdom.

### Data analysis

Using SPSS v. 25, descriptive statistics (n,%; PMS  $\pm$  SD) and bivariate analyses (Pearson's Chi square, Mann Whitney) were conducted to determine factors associated with the study outcomes, with a *P* value statistically significant at  $<0.05$ .

## Results

### Sample characteristics

For the Saudi public community, 1494 participants fully completed the survey. Leading catchment area was central region 80.7%. Males comprised 21.6% of sample, while females were 78.4%, and their Mean  $\pm$  SD of age was  $33.7 \pm 11.3$  years. Almost 83% had university level of education, and 44% were employed. More than 75% were financially comfortable, yet only 45% had full dental coverage.

For the Saudi dentists, 246/262 (94%) eligible dentists responded to the questionnaire, among whom males comprised (64%) of

the sample, while (36%) were females, with a Mean  $\pm$  SD of age  $32 \pm 7.6$ . Almost 49% were general dentists, while others were of various specialties, with Mean  $\pm$  SD of work experience  $7.2 \pm 7.3$  years.

Public and dentist's perception about Dental Stem Cells

The PMS  $\pm$  SD of public knowledge was  $25.5 \pm 25.9$ , while their attitude was  $80.2 \pm 27.0$ .

Regarding the public knowledge, those who were asked about whether the procedure of collecting stem cells is invasive scored the highest (59.3%), followed by those who think that dental stem cells can treat many diseases (23.9%), then people who think that dental stem cells can regenerate a lost tooth (21.8%), and the least were those who agreed that teeth can be a source of stem cells (15.7%). Factors associated with higher knowledge scores were younger age groups (<30 years), (PMS  $\pm$  SD =  $29.2 \pm 28.1$ ), single participants (PMS  $\pm$  SD =  $28.6 \pm 27.8$ ), unemployed (PMS  $\pm$  SD =  $27.6 \pm 26.9$ ) and those with full dental coverage (PMS  $\pm$  SD =  $27.3 \pm 27.1$ ), compared to their counter groups,  $P < 0.001$ ,  $P < 0.001$ ,  $P = 0.001$  and  $P = 0.030$ . Regarding the public attitude towards dental stem cells, those who would like to have more information about dental stem cells scored the highest (88.6%), followed by participants who would donate a lost tooth for dental stem cells research and therapeutic purposes (86.2%) and (84.9%), respectively. More than half of the participants (60.8%) from the public group would like to enroll in a national tooth bank. Female participants (PMS  $\pm$  SD =  $81.9 \pm 25.2$ ), older age groups ( $\geq 30$ ) (PMS  $\pm$  SD =  $82.9 \pm 24.8$ ), married participants (PMS  $\pm$  SD =  $82.5 \pm 24.1$ ), university educated (PMS  $\pm$  SD =  $81.2 \pm 26.4$ ) and employed participants (PMS  $\pm$  SD =  $82.1 \pm 25.9$ ) had higher attitude scores in comparison to their counter groups,  $P < 0.001$ ,  $P < 0.001$ ,  $P = 0.010$ ,  $P = 0.001$  and  $P < 0.001$  respectively. They reported that their best source of information on this topic would be dentists [Figure 2]. Their responses to the knowledge and attitude statements are tabulated [Table 1].

For the Saudi dentists, their PMS  $\pm$  SD of perception towards dental stem cell research for regenerative purposes was  $74.5 \pm 15.6$ .

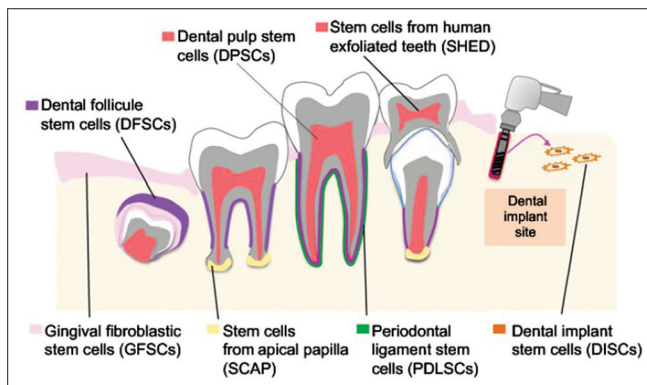


Figure 1: Sources of dental stem cells<sup>[9]</sup>

To elaborate, the highest perception score was achieved by dentists who think that regenerative therapy should be incorporated into dentistry 231 (93.9%). Similar results were obtained from dentists who think that regenerative treatments should be tested on animals before clinical testing 228 (92.7%), followed by those who think that dental associations should regulate the use of stem cells in dentistry 227 (92.3%). Interestingly, about three-quarters of the dentists in our study reported that they think regenerative dental treatment would be a better option than tooth implant and are willing to deliver treatments that involve embryonic stem cells. Moreover, the majority of them think that regenerative dental treatment has successful outcomes. However, about 67% are concerned about health hazards that might be associated with the use of stem cells in regenerative dentistry. Their responses are tabulated in Table 2. Factors associated with higher perception scores were those with more experience ( $\geq 5$ ) PMS  $\pm$  SD =  $77.0 \pm 14.9$ , in comparison to their counter group,  $P = 0.032$ . Almost half of the dental practitioners didn't receive any education regarding stem cells in dental treatment, but the prevalence of those willing to attend training on regenerative stem cell therapies was 219 (89%), while those willing to save teeth and dental tissue for regenerative purposes was 223 (90.7%). Their responses also revealed that dentists who read journals more frequently are significantly more willing to save teeth by regenerative dental treatment,  $P < 0.045$ . Moreover, dentists who had higher perception scores towards dental stem cells (PMS  $\pm$  SD =  $76.3 \pm 14.8$ ) were significantly more willing to save teeth/dental tissue for regenerative dental treatment, in comparison to those who didn't have the intention (PMS  $\pm$  SD =  $59.9 \pm 15.6$ ),  $P < 0.001^*$ . An example of those who have a higher perception are dentists using regenerative procedures in their practices, such as membranes, scaffolds, or bioactive materials. A number of obstacles have been reported by Saudi dentists that might hinder a prospective Saudi dental stem cell bank [Figure 3], in which higher cost was the mostly reported factor.

Discussion

The present study is considered the first one in Saudi Arabia to explore the knowledge and attitude of the public toward DSC banking, and to measure the dentists' willingness to be part in this process. Several studies in the past have already surveyed the public opinions regarding cord blood banking. An example of these studies is the one directed by Jawdat *et al.* recently in Saudi Arabia.<sup>[15]</sup> Unfortunately, most of the participants (66.1%)

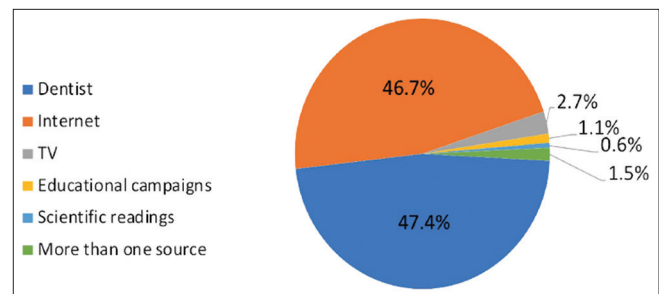


Figure 2: Public Sources of Information about Dental Stem Cells

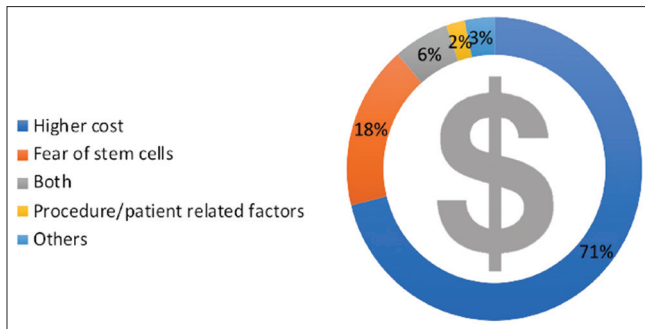
**Table 1: Public knowledge and attitude towards dental stem research for regenerative purposes**

No.	Public knowledge/attitude	Negative response n (%)	Positive response n (%)
K1	Do you know that stem cells from dental tissues are used to treat many diseases?	1137 (76.1%)	357 (23.9%)
K2	Do you know that teeth can also be source of stem cell collection?	1260 (84.3%)	234 (15.7%)
K3	Do you know that the tooth if lost can be regenerated using stem cells?	1169 (78.2%)	325 (21.8%)
K4	Do you think the procedure of collecting stem cells is invasive?	608 (40.7%)	886 (59.3%)
A1	Would you like to have more information on stem cell banking?	170 (11.4%)	1324 (88.6%)
A2	Would you like to enroll in National dental stem cell banking?	585 (39.2%)	909 (60.8%)
A3	Would you like to donate a lost tooth for stem cell therapeutic purposes?	225 (15.1%)	1269 (84.9%)
A4	Would you like to donate a lost tooth for stem cell research purposes?	206 (13.8%)	1288 (86.2%)

n: frequency, %: percentage

**Table 2: Dentists' perception towards dental stem research for regenerative purposes**

No.	Perception of dentists	Negative perception n (%)	Positive perception n (%)
P1	Should regenerative therapy be incorporated into dentistry? (+)	15 (6.1%)	231 (93.9%)
P2	Do you think that regenerative dental treatment will be a better treatment option than tooth implant placement? (+)	60 (24.4%)	186 (75.6%)
P3	Do you think stem cells and regenerate treatments should be tested on animals prior to clinical testing? (+)	18 (7.3%)	228 (92.7%)
P4	Would you be willing to deliver dental treatments that involve embryonic stem cells sourced from a human fetus? (+)	60 (24.4%)	186 (75.6%)
P5	Are you concerned about any potential health hazards regarding the use of stem cells as part of regenerative dentistry? (-)	82 (33.3%)	146 (66.7%)
P6	Do you believe there is a potential that stem cell clinics will deliver future dental treatments? (+)	65 (26.4%)	181 (73.6%)
P7	Do you believe that dental professional associations should regulate the use of stem cell and regenerative dentistry? (+)	19 (7.7%)	227 (92.3%)
P8	What is your assessment of regenerative dental treatment outcomes? (+)	71 (28.9%)	175 (71.1%)
P9	After non-surgical root canal treatment, would the healing of periapical tissues be enhanced by tissue engineering? (+)	87 (35.4%)	159 (64.6%)



**Figure 3: Perceived Obstacles to Initiating a Dental Stem Cells Bank**

had poor knowledge about cord blood banking. Upon asking whether they prefer public or private banks, the majority of them had positive attitude toward public storage. Another study is the one conducted by D. Vignesh *et al.* in India among 300 pregnant women.<sup>[17]</sup> About (77%) had inadequate knowledge about stem cells explained by their inadequate education and low socioeconomic status. They also reported that they would prefer public over private hospitals for stem cells banking due to less cost. In accordance with our study, dental practitioners also reported that cost might be the biggest barrier to hinder a prospective Saudi dental stem cell bank [Figure 3]. Nevertheless, dental stem cell banking is more cost-effective and less invasive than cord blood. Cost might have a huge impact in people's decision toward cord blood or DSC banking since we live in

an economically driven world. As a result, the level of a dental stem cells registry in Saudi Arabia may be preferred to be governmental. The non-profit government organizations having control over dental stem bank is more trustworthy since a lot of health services are provided by governmental controlled institutions. This sector will be more efficient to provide resources, train their employee, and provide easy access for the citizens for such services.

Saudi public must be aware about the presence, source, and therapeutic effects of DSC because they will be the suppliers or donors of DSCs in this process. If they are not aware about it, they will not donate or participate in a future dental stem cell bank. Primary care practitioners are the first line of contact with patients for education and raising awareness about different health issues, which emphasizes on the important role of primary care centers. For patients seeking dental treatment, the proper education and referral for treatments involving DSCs should be done by primary care dental practitioners. Educational health campaigns can also provide the public with great amount of information about the therapeutic benefits of DSC banking for their health in the future. Since almost half of our subjects reported that internet and social media are their best source of information, such method can be utilized to increase the public awareness about DSC banking because it can reach the majority of the public groups. Highest percentage of lower awareness levels was recorded in male group ( $23.36 \pm 25.17$ ) compared

to female group ( $26.08 \pm 26.12$ ), thus it would be beneficial to target male clusters areas such as coffee shops and sports areas. Employees group of the public also showed lower knowledge toward DSC banking, so awareness programs by their institutions can improve their knowledge of such life-saving therapeutic services.

Saudi dentists' perception about DSC banking should be addressed since they are the service providers involved in the stem cells collecting process. The knowledge of Saudi dentist about DSC banking can be improved by workshops and different training courses to emphasize on the promising therapeutic effects of DSC banking in fields of dentistry and medicine. Attending seminars and journal clubs are also recommended to be updated about the recent research on DSC.

In 2008, the American Academy of Pediatric Dentistry published a policy on dental stem cells and dental stem cell banking. This policy emphasized on the importance of using dental stem cells in dentistry and demonstrated how dentists are poised to take a leadership position in this emerging field.<sup>[18]</sup> In 1966 the term tooth bank was first brought up.<sup>[19,20]</sup> With the huge improvement of cryopreservation technique, the first tooth bank was set up in 2004 at National Hiroshima College in Japan and named "Three Brackets".<sup>[20]</sup> A considerable number of teeth were stored for future therapeutic benefits. "Three Brackets" was followed by Nagoya University tooth bank in 2007 (Kyodo, Japan). This trend expanded further to the collaboration of Hiroshima College with Taipei Medical University to develop the nation's first tooth bank in 2008. Most of dental stem cell banks world-wide have been introduced as private organization or small companies and expanded internationally such as BioEden (Austin, Texas), StemSave, and Store-a-Tooth (USA). Recently, the concept of stem cell-based therapy has gained more recognition, and the total number of tooth banks are increasing.<sup>[21]</sup>

The workflow starts by partnership with dentists to collect the sample and send it to the lab, where stem cell processing and cryopreservation take place. The laboratory must follow approved quality control measures regarding the removal of microbial oral flora from the tooth and accusation of viable stem cells. They should also ensure that the cultured cells present the standard set of cell surface markers for mesenchymal stem cells (MSCs). Cryopreservation, which is the process of preservation of living cells and tissue at extremely low temperature, is applied to the cells by cryoprotectant solution. This solvent should be able to prevent the formation of ice crystals and maintain the viability of cells. The temperature is gradually reduced to freezing by programmable controlled-rate freezers, which will be transported later to liquid nitrogen freezers at vapor phase for long-term storage at ultra-low temperature to be used in the future.<sup>[22,23]</sup>

Dental Stem Cells Current Uses, Near Future, and Long-Term:

DSCs were successfully applied *in vivo* and *in vitro* to treat multiple dental conditions. For instance, DSCs collected from third molars

were clinically used in 17 human subjects to regenerate alveolar bone of at least 1.5 cm defects.<sup>[24]</sup> Moreover, it was experimentally and clinically evident that autologous periodontal ligaments cells may have therapeutic benefits in the treatment of periodontitis.<sup>[25]</sup> There are other encouraging examples of utilizing DSCs in dentistry which include: pulp revascularization of immature permanent teeth, bone formation around dental implants, and drug screening.<sup>[26-29]</sup> Pulp regeneration for mature teeth is an expected alternative treatment modality for diseased dental pulp tissue.<sup>[30]</sup> In addition, it has been reported that DSCs isolated from SHED were used in rats for the purpose of correcting cranial defects, providing an upcoming remarkable advancement in the field of craniofacial surgery.<sup>[22,31]</sup> Stem cell researchers have further advanced to look into the possibility of re-growing a whole tooth. Third dentition or bioengineered teeth is a procedure to produce tooth buds by adding both dental pulp and bone marrow on a scaffold and implanting them surgically into the host. Few months later, it resulted in well-formed enamel, dentin, pulp, cementum, and PDL surrounded by regenerated alveolar bone, leading to a future method that could possibly be applied in humans.<sup>[32]</sup> Another breakthrough in the science of stem cells for tooth regeneration was created by Dr. Mao in Columbia University. His approach was novel by using cell-homing technique to regrow a correctly shaped tooth scaffolds in rats in a period of 9 weeks. This scaffold attracts more stem cells and applied directly in the rat *in vivo* without using petri dishes.<sup>[33]</sup> By the time this technique is applied in dental clinics, the cost is expected to be between 2500\$-3500\$.<sup>[22,34]</sup>

Dental Stem Cells Uses in the Medical Field:

Recent literature has reported promising and possible futures uses of DSCs in the treatment of many medical conditions. To illustrate, dental pulp stem cells were used to reconstruct the corneal epithelium after chemical burn in an animal model.<sup>[35]</sup> DSCs have also showed remarkable therapeutic effects in myocardial Infarction patients where it decreased the infarct size and improved cardiac function.<sup>[36]</sup> Furthermore, stem cells isolated from extracted third molars were able to differentiate into hepatocytes *in vitro*, increasing successful outcomes in treating liver disease.<sup>[37]</sup> For diabetic patients, DSCs have been used to secrete insulin and regulate the immune system by inhibiting T-cell response *in vivo* and *in vitro* which is a promising solution for treating diabetes.<sup>[22,38-40]</sup>

Limitations of Dental Stem Cells:

1. There is a chance of immune rejection, so the use of autologous cells or intake of immunosuppressive drugs to avoid such complication might be needed.
2. Most of the researches were conducted in animal models. Thus, confirmation of clinical application is needed.
3. Formation of teeth like structure is not yet possible to replace the natural tooth. Dental blood vessels and nerves need more research to be engineered to coincide with the dental stem cells.<sup>[41]</sup>

## Conclusion

The Saudi public community had poor knowledge about the therapeutic and research benefits of dental stem cells, yet high degree of attitude to enroll in a future Saudi dental stem cell bank. Saudi dentists had moderately high levels of perception towards dental stem cell research. Enhancing the Saudi dentists' perception will eventually encourage them to actively participate in a future Saudi dental stem cell bank. The authors recommend marketing campaigns to boost the public knowledge in community using network, social media, and promotion materials in dental clinics. For the dentists, educational training and calling for specialists would be beneficial to enhance their awareness in this regard. In general, calling for sponsors and international collaborators for tissue acquisition and banking, seeking governmental grants, and conducting need assessment are recommended in order for the next tooth bank to be in the middle east.

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## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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## Conflicts of interest

There are no conflicts of interest.

## References

- Sedgley C, Botero T. Dental stem cells and their sources. *Dent Clin North Am* 2012;56:549-61.
- Chalisserry EP, Nam SY, Park SH, Anil S. Therapeutic potential of dental stem cells. *J Tissue Eng* 2017;8:204173141770253. doi: 10.1177/2041731417702531.
- Sharpe PT. Dental mesenchymal stem cells. *Development* 2016;143:2273-80.
- Martinez Saez D, Sasaki R, Neves A, da Silva M. Stem cells from human exfoliated deciduous teeth: A growing literature. *Cells Tissues Organs* 2016;202:269-80.
- Majeski J. Dental stem cells in research and practice. *Access* 2009;26:24-6.
- Shi S, Chai Y, Slavkin H. Emerging opportunities for the next generation of dental implants? *Dent Today* 2009;28:98-9.
- Duailibi M, Duailibi S, Young C, Bartlett J, Vacanti J, Yelick P. Bioengineered teeth from cultured rat tooth bud cells. *J Dent Res* 2004;83:523-8.
- Iohara K, Nakashima M, Ito M, Ishikawa M, Nakasima A, Akamine A. Dentin regeneration by dental pulp stem cell therapy with recombinant human bone morphogenetic protein 2. *J Dent Res* 2004;83:590-5.
- Young C, Terada S, Vacanti J, Honda M, Bartlett J, Yelick P. Tissue engineering of complex tooth structures on biodegradable polymer scaffolds. *J Dent Res* 2002;81:695-700.
- Ueda M, Yamada Y, Ozawa R, Okazaki Y. Clinical case reports of injectable tissue-engineered bone for alveolar augmentation with simultaneous implant placement. *J Prosthet Dent* 2005;94:560.
- Hibi H, Yamada Y, Ueda M, Endo Y. Alveolar cleft osteoplasty using tissue-engineered osteogenic material. *Int J Oral Maxillofac Surg* 2006;35:551-5.
- Mankani MH, Krebsbach PH, Satomura K, Kuznetsov SA, Hoyt R, Robey PG. Pedicled bone flap formation using transplanted bone marrow stromal cells. *Arch Surg* 2001;136:263-70.
- Marion NW, Mao JJ. Mesenchymal stem cells and tissue engineering. *Methods Enzymol* 2006;420:339-61.
- Alhadlaq A, Mao J. Tissue-engineered osteochondral constructs in the shape of an articular condyle. *J Bone Joint Surg Am* 2005;87:936-44.
- Jawdat D, AlTwijri S, AlSemari H, Saade M, Alaskar A. Public awareness on cord blood banking in Saudi Arabia. *Stem Cells Int* 2018;2018:1-5.
- Manguno C, Murray P, Howard C, Madras J, Mangan S, Namerow K. A survey of dental residents' expectations for regenerative endodontics. *J Endod* 2012;38:137-43.
- Vignesh D, Vanishree N, Naveen N, Anushri M, Narayan R, Raveendran M. Pregnant women's knowledge and attitude toward role of stem cells in dentistry: A cross-sectional study. *Indian J Oral Health Res* 2017;3:57.
- O Council. Policy on stem cells. *Pediatr Dent* 2008-2009;30(Suppl 7):84.
- Coburn RJ, Henriques BL, Francis LE. Development of an experimental tooth bank using DEEP freeze and tissue culture techniques. *J Oral Ther Pharmacol* 1966;2:445.
- Huang Y, Yang J, Wang C, Lee S. Dental stem cells and tooth banking for regenerative medicine. *J Exp Clin Med* 2010;2:111-7.
- Jain A, Bansal R. Current overview on dental stem cells applications in regenerative dentistry. *J Nat Sci Biol Med* 2015;6:29. doi: 10.4103/0976-9668.149074.
- Krasner P1, Verlander P. Stem cells in dentistry and medicine: The dentist's role. *Dent Today* 2011;30:128, 130-4; quiz 135.
- Gupta S, Narwal A, Hooda A. Dental stem cells - Sources and identification methods. *CHRISMED J Health Res* 2019;6:1.
- d'Aquino R, De Rosa A, Lanza V, Tirino V, Laino L, Graziano A, *et al.* Human mandible bone defect repair by the grafting of dental pulp stem/progenitor cells and collagen sponge biocomplexes. *Eur Cell Mater* 2009;18:75-83.
- Feng F, Akiyama K, Liu Y, Yamaza T, Wang TM, Chen JH, *et al.* Utility of PDL progenitors for *in vivo* tissue regeneration: A report of 3 cases. *Oral Dis* 2010;16:20-8.
- Huang GT. A paradigm shift in endodontic management of

- immature teeth: Conservation of stem cells for regeneration. *J Dent* 2008;36:379-86.
27. ClinicalTrials.gov. Tissue characterization in teeth treated with a regeneration protocol. <http://clinicaltrials.gov/ct2/show/NCT00881907>. [Last accessed on 2010 Nov 01].
  28. Mangano C, De Rosa A, Desiderio V, d'Aquino R, Piattelli A, De Francesco F, *et al.* The osteoblastic differentiation of dental pulp stem cells and bone formation on different titanium surface textures. *Biomaterials* 2010;31:3543-51.
  29. Okamoto Y, Sonoyama W, Ono M, Akiyama K, Fujisawa T, Oshima M, *et al.* Simvastatin induces the odontogenic differentiation of human dental pulp stem cells *in vitro* and *in vivo*. *J Endod* 2009;35:367-72.
  30. Yang JW, Zhang YF, Wan CY, Sun ZY, Nie S, Jian SJ, *et al.* Autophagy in SDF-1 $\alpha$ -mediated DPSC migration and pulp regeneration. *Biomaterials* 2015;44:11-23.
  31. de Mendonça Costa A, Bueno DF, Martins MT, Kerkis I, Kerkis A, Fanganiello RD, *et al.* Reconstruction of large cranial defects in nonimmunosuppressed experimental design with human dental pulp stem cells. *J Craniofac Surg* 2008;19:204-10.
  32. Zhang W, Abukawa H, Troulis MJ, Kaban LB, Vacanti JP, Yelick PC. Tissue engineered hybrid tooth-bone constructs. *Methods* 2009;47:122-8.
  33. Kim K, Lee C, Kim B, Mao J. Anatomically shaped tooth and periodontal regeneration by cell homing. *J Dent Res* 2010;89:842-7.
  34. Stem Cells for Dental Implants and Tooth Regrowth. *Stem Cell: The Magazine*. 2019. Available from: <https://stemcellthemagazine.com/2018/06/stem-cells-for-dental-implants-and-tooth-regrowth/>.
  35. Gomes JA, Geraldes Monteiro B, Melo GB, Smith RL, Cavenaghi Pereira da Silva M, *et al.* Corneal reconstruction with tissue-engineered cell sheets composed of human immature dental pulp stem cells. *Invest Ophthalmol Vis Sci* 2010;51:1408-14.
  36. Gandia C, Armiñan A, García-Verdugo JM, Lledó E, Ruiz A, Miñana MD, *et al.* Human dental pulp stem cells improve left ventricular function, induce angiogenesis, and reduce infarct size in rats with acute myocardial infarction. *Stem Cells* 2008;26:638-45.
  37. Ikeda E, Yagi K, Kojima M, Yagyuu T, Ohshima A, Sobajima S, *et al.* Multipotent cells from the human third molar: Feasibility of cell-based therapy for liver disease. *Differentiation* 2008;76:495-505.
  38. Huang CY, Pelaez D, Dominguez-Bendala J, Garcia-Godoy F, Cheung HS. Plasticity of stem cells derived from adult periodontal ligament. *Regen Med* 2009;4:809-21.
  39. Pierdomenico L, Bonsi L, Calvitti M, Rondelli D, Arpinati M, Chirumbolo G, *et al.* Multipotent mesenchymal stem cells with immunosuppressive activity can be easily isolated from dental pulp. *Transplantation* 2005;80:836-42.
  40. Yamaza T, Kentaro A, Chen C, Liu Y, Shi Y, Gronthos S, *et al.* Immunomodulatory properties of stem cells from human exfoliated deciduous teeth. *Stem Cell Res Ther* 2010;1:5.
  41. Caracappa J, Gallicchio V. The future in dental medicine: Dental stem cells are a promising source for tooth and tissue engineering. *J Stem Cell Res Ther* 2019;5:30-6.