Dental Patient Treatment Chair: A Review

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Abstract
A dental unit chair is an indispensable medical device for examination, diagnosis and treatment, designed to anatomically support a dental patients and practitioners during treatment, through mechanisms that permit recline and articulation. This paper reviews technological approaches to dental patient chair design of various researchers and inventors obtained from high-quality databases and repository, including public domain websites, and seven academic literature databases, consisting of ISI Web of Science, Scopus, PubMed, IEEE, Google Scholar, Wiley and Science Direct from 2010-2023. The methodology adopted for the study is a six-step systematic literature review approach that followed preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines. Sixty-four papers were identified from the databases, and twenty-three met inclusion criteria. Scientific studies involving design and development was   more prevalent with 52%, in which two paper, one each performed finite element analysis of system and solidworks. The scientific- based design and development of dental chair were electrical, while a proportion of 92% of all studied papers involved technological initiatives to recline and articulate dental chair.

Keywords: Dental chair, PRISMA, mechanism, technology, analysis, design

I.   Introduction

Dental chair has gradually evolved over a span of decades, from basic wooden chair to modern and highly technologically advanced, comfortable and versatile seat. Dental unit chair is an indispensable medical device, specially designed to support a patient's body that is undergoing dental procedure [1][2][3]. It supports a patient's body, like a recliner, but articulated, so that dentist can recline patients to virtually any position. The dental unit chair is one of the most important element in dental workstation for both for the patients and professionals, developed ostensibly to providing psychological therapy, patient satisfaction and safety at all ponged positions for patients, as well as improving ergonomics and productivity of the practitioners[4]. Therefore, development of dental chair is premised on sustenance of dentistry and quality oral care for patient. The sophistication of dental chair to meet ergonomic and functionality needs of specific areas of dentistry led to integration of tremendous technological advancements, morphing it into medium-to- high end medical device, a dental chair unit. The dental profession began in ancient Egypt where pieces of gold and ivory were used to replace missing teeth. However, first real dental chair was invented in 1790 by an American dentist, Dr. Josiah Flagg, who modified his writing chair into the first dental chair, incorporating a working tray, constructed wider armrests and introduced a small headrest to improve functionality. In 1960, Dr. Naughton, developed what is widely believed to be the birth of modern dental chairs, with a highly recline-able chair. This became a model, on which many manufacturers tweaked and added new features. How dental patient treatment chair has performed the rudimentary functions of recline and articulation has dominated research space, hence, the study on dental patient treatment chair design: a review.

II.   Materials and Methods

This review aims at identifying research papers published in high-quality journals in scientific repositories. General and medical dictionaries and high-quality databases, including public domain websites, and seven academic literature databases, consisting of ISI Web of Science, Scopus, PubMed, IEEE, Google Scholar, Wiley and Science Direct were searched for journals with related research theme: dental patient treatment chair design. Evidence search strategy were included in Table 1.

The methodology adopted for the study is systematic literature review (SLR) approach. The concept provided an organized framework of

previous studies for detailed analysis, discovery of knowledge, trends and establishment of research gaps [5]. The six -step systematic literature review methodology included: planning and formulation of the problem search in the literature, collection and evaluation of data, analysis and synthesis of data, interpretation, and results presentation.

2.1 Planning and Formulation of the Problem Search. The review identified research papers published in high-quality journals in scientific repositories. General and engineering dictionaries and high-quality databases, including public domain websites, and five academic literature databases, consisting of ISI Web of Science, Scopus, IEEE, Google Scholar and Science Direct

were searched for journals with related research theme: design of dental chair. *Mentefactor* concept of design of dental chair was applied to develop ideogram to understand the complexity and conceptualize it [6]. From the ideogram, were obtained iso-ordination, supra-ordination, infra-ordination and exclusion, which were determinants in identifying search words, inclusion and exclusion criteria respectively. The procedure for paper search in the literature followed Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (The Preferred Reporting Items for Systematic and Meta-Analysis)[7]. Evidence search strategy included initial search syntax shown on Table 1.

Table 1: Search Script for Each Database (Field Data,2023)

DB	Syntax	Resulting Papers *val/ref/res*
WOS	Initial filter: \<Title\> and year ≥ 2010 (Improved design OR Design) AND (dental chair OR dentistry chair OR dental unit chair)	2/3/7
Science Direct	Initial filter: \<Title\> and year ≥2010 Dental chair , (Dental chair AND Design)	4/6/13
IEEE	Parallel filter: (year ≥ 2010) Review, study, design OR Dentistry chair, OR dental unit OR dental unit chair OR dental chair unit	3/5/9
Google Scholar	Initial filter: \<Title\> and year ≥2010 Dental chair , (Dental chair AND Design)	5/10/12
Scopus	Initial Filter: \< Article Title, Abstract, Keyword\> and year ≥ 2010 (Ergonomic) AND (Design OR development) AND (dental chair OR dental unit chair)	2/8/15
Other DBs	Initial filter: \<Title\> and year ≥2010 Dental chair , (Dental chair AND Design)	7/11/27

2.2 Collection and Evaluation of Data.
Three reviewers, DVU, ZET, and OED screened the article title and consequently studied the paper abstracts for validity. Duplicates of records were removed. At this instant, reference list was drawn and full papers critically reviewed for eligibility, based on inclusion criteria.   The following eligibility criteria were observed in the study.
a. Full text reviews of international published journals between 2010 and 2023 in English language
b. Paper with evidences and discussion on different methodological approaches in study of dental chair.

c. Systematic reviews and meta-analyses of dental chair primary studies.
Papers that passed screening protocol were eligible and valid, hence, considered for inclusion in the literature review, as applicable in PRISMA guideline. Figure 1 represents an overview of PRISMA guideline. The authors' interactive review process provided agreement for the content analyses and adoption of consensus on some terms not explicitly expressed. The review scheme extracted sixty four papers from initial eighty three papers. The eligible papers were characterized in terms of study interest.
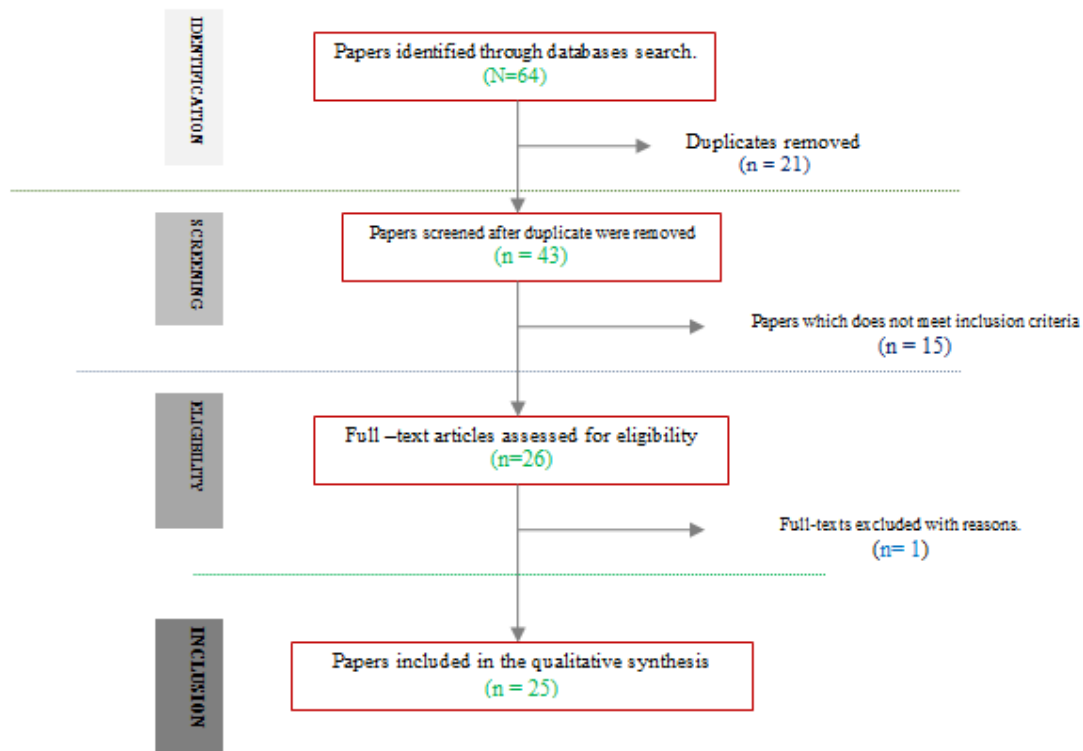
Figure 1: PRISMA Flow Algorithm (PRISMA, 2015)

2.3   Collection and Evaluation of Data

Table 2 shows the yearly distribution of publications on dental chair, while Figure 2 shows data visualization of the distribution. Based on Table 2, 2020 has the highest publications per year on dental chair, with 5 papers (21.7%), and 60% of the publications in scientific study. The Figure 2 represents the most frequency of papers recorded for scientific studies for the period. Scientific study accounted for 13 papers (52%) of the reported literature. There is a growing interest among researchers on dental chair since 2019. 2020-2022 account for 13 papers (52%) of the researches took place 2020-2022, indicating increasing research interest on dental chair study.

Table 2: Yearly Distribution of Publications on Dental Chair (Field Data, 2023)

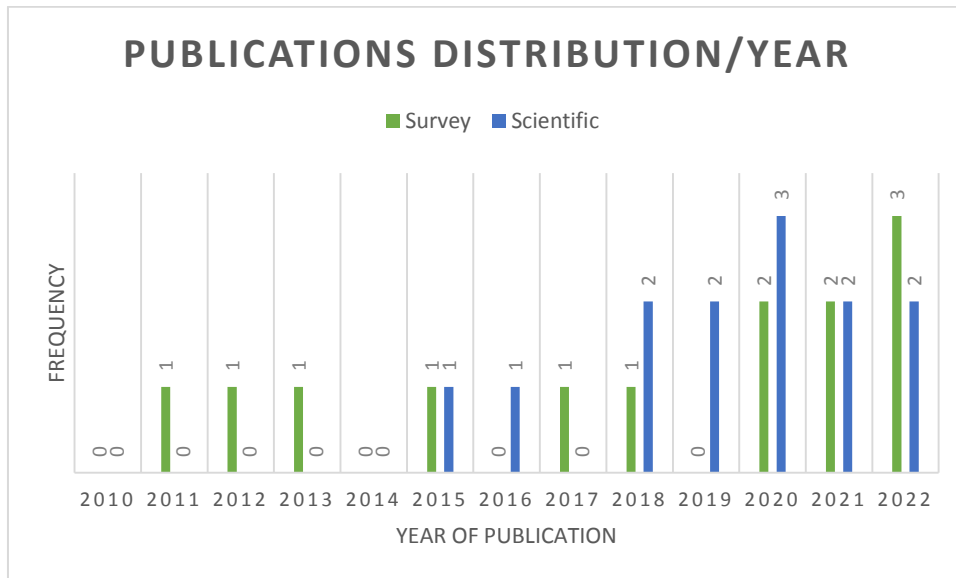| Year of Pub.	Study	
	Survey	Scientific
2010	N/A	N/A
2011	[8]	N/A
2013	[9]	N/A
2014	N/A	N/A
2015	[10]	[11]
2016	N/A	[12]
2017	[13]	N/A
2018	[14]	[15] [16]
2019	N/A	[17] [18]
2020	[19] [20]	[1][2][21]
2021	[22][23]	[24][25]
2022	[26][27][40]	[28][29]

Figure 2: Distribution of Publications/ Year (Field Data, 2023)

Table 3 shows the methodology adopted by various researchers. Survey study and scientific study were the predominant methodologies.

2.4   Analysis and Synthesis of Data

[9] conducted a survey study on work setting of dental chair. Similar study was performed by [19] on perceptions of dentists and allied workers to dental chair. These works are as expository as invaluable to design of dental chair.[10] carried out further study on characterization of dental chair by studying comparatively, pediatric dental chair and traditional dental chair. [8] provide groundwork for dental chair design with a study on design considerations of a working dental chair. Ergonomic improvement in work settings, including dental chair, has dominated research space. Quite a good number of reported papers are well suited within ergonomic research. [14][22] work were on dental chair-based ergonomics. [26] evaluated satisfaction factors with a dental unit chair system in S. Korea to a dentist.[23] work was on influence of design of dentist's chair in the body posture for dentists with different working experience.

On the other planks, dental chair was studied on different tiers of design. Modeling is an essential and modern technique of representing and studying real life system. [24] analyzed Morrison Chair. [25] analyzed dental chair system and recommended re-engineering traditional dental chair and integration of digital dentistry to provide exceptional ergonomic design. [12] carried out structural analysis of flexible wearable chair using ANSYS-based finite element analysis (FEA). [15] performed similar study through modeling a smart dental chair, with a landmark development process and reconfiguration in accordance with TIS 2610-2556 prototype.[17] studied dental chair lift/ articulation system, with a concept to implement a modernized dental chair using voice recognition control system. [29] performed structural analysis and optimization of lift design, using SOLIDWORKS- based finite element methodology (FEM). The work recommended further study and mechanism to adjust the inclination of head rest and foot rest pad of the dental chair. Simulation tests a model of real-life scenarios, which, some researchers availed to provide deep insights. [2, 18] carried out simulation research and motion control of dental chair in the medical application. [1] performed dental unit prototyping with electric dental chair and dental light parameters. The work utilized pneumatic technology for lift and linear actuator as a back drive for articulation /reclining of dental chair.

Table 3: Research Designs Adopted By Various Researchers (Field Data, 2023)

Methodology	Ref.
Survey Research	[8-10][13][14][19][20][22][23][26-27][30]
Scientific (Design/ Development)	[1][2][11][12][15-18][21][24][25] [28][29]

Table 4 shows methodology for analysis. With numerical methodology and ever-evolving computational engineering tools, systems can be studied more precisely than ever. Finite element analysis (FEA) was generally used to study structural behaviour of dental chair by the researchers. [12] studied structural analysis of flexible wearable chair, using analysis of system (ANSYS).[29] applied solidworks on structural analysis of scissor link that led to optimization of scissor link parameters resulting to efficient lift design.

Table 4: Methodology for Analysis (Field Data, 2023)

Methodology for Analysis	Tool	Ref
Finite Element Analysis(FEA)	Analysis of System(ANSYS)	[12]
	Solidworks	[29]

Table 5 shows the design concept of the researchers. Most researchers adopted system-wide approach in dentistry chair study. [11] designed a working chair for dentist-therapist using wood. [16] studied ergonomic chair in educational setting. [2][18] simulated dental chair for practice of dental medical students. [24] analyzed Morrison chair. To articulate, yet recline a dental chair effectively and efficiently was the focus of many researchers. [1] developed electric dental chair prototype with pneumatic technology for lift and linear actuator as a back drive for articulation /reclining of dental chair. Majority of research on control lean towards artificial intelligence-based electronic control.[15] paper focuses on reconfiguration of dental chair in accordance with TIS 2610-2556 prototype.[17] designed a contact-less implementation of dental chair using voice recognition control system. Pedestal is another component of dental chair that received rare research attention. [21] studied how to modify dental chair to accommodate wheelchair bound patients and general population.[29] work represents a reported novel adoption of scissor link in development of medical devices.

Table 5: Design Concept of Researchers (Field Data, 2023)

Design concept			Ref
Dental chair component	Chair		
	Pedestal		[21] [30]
	Control	Lift Drive	[1]
		Electronic	[15]
			[17]
	System wide		[11][12][16][18][2][24][25][28]

However, there was no reported independent and verifiable headrest-centric study known to the researcher yet. Double articulated head rest has been noted to have dominated research and market spaces. At this instant,[29] recommended further study and mechanism to adjust the inclination of head rest and foot rest pad of the dental chair.

Table 6 shows the design objective researchers. Generally, the researchers were focused on developing improved design that would optimize performance of dental chair.[28] design was propelled by aesthetics, of a new- moon shape main body that conceal complex mechanism. What could be considered as economic analysis was reported by [27], who performed estimation of dental chair-hour cost in the faculty of dentistry of the University of Cuenca. However, no study has been reported on techno-economic analysis of dental chair till date.

Table 6: Design Objective of Researchers (Field Data, 2023)

Analytical Approach	Ref
Technology	[2][11][12][14-18][21][22][24][25][29]
Economics	[27]
Aesthetics	[28]
Techno-economic analysis(TEA)	N/A

2. 5   Interpretation

Google scholar and other DBs provided 5 and 7 papers respectively. WOS and Scopus contributed the least number of papers, 2. Year 2020 had the highest frequency of paper publications/year, mostly on scientific studies. Researchers were more involved in scientific study in 2018-2020, with 13 papers (52%) providing technological solution to improving recline/articulation and general ergonomics of dental chair. Interest of most researchers in dental chair dwelt on electronic control system design using AI to efficiently recline the device. The choice of AI reflects current technological demand, but may prove costly in capital outlay, operations and maintenance (O&M), just like products in marketplace, thereby negatively impacting on availability and affordability of the device.

History of dental chair is replete with initiatives to improve recline-ability, and ultimately ergonomics. However, the trend has been dynamic, from mechanical, pneumatic, hydraulic, electric, and now electronic technology. The extant technology are deemed ineffective to recline according to dental job demand, hence, there is increasing research interest in adaptation of artificial intelligence (AI) to drive recline and articulation of dental chair and bring patient to prong position. Further to smart dental chair, researchers have explored the use of biometric (voice recognition) system as a means to control recline of dental chair [17]. Implementation of AI, as seen, requires some form of reconfiguration of the system to a standard, such as TIS 2610-2556 prototype [15].The design concepts have potential to significantly improve maneuverability of dental chair, but ergonomic and economic concerns subsist. As could be observed, the trend of technology in the design is electricity-centric.

[30] avers that dental chairs were designed more for dentists' utility, with less pleasurable dental experience for patients, with a typical comfort gap. The head-to-neck gap, improper cushioning of the headrest, and in-built but static headrest are noticeable design constraints that affect articulation and head support of the patients. Reported initiatives to ameliorate headrest challenges included right-sized dental headrest with appropriate cushion design and innovative articulation features, as well as dental- engine-powered headrest design. The introduction of dental engine and array of visions were the game changer but seriously undermined by cost, availability and accessibility of the device.

Available reports have not highlighted a cost-effective technological breakthrough in addressing headrest problem.[29] recommended further study and mechanism to adjust the inclination of head rest and foot rest pad of the dental chair.

[8] identified medical, aesthetics, structural, economics, technology and ergonomics as considerations for design of working dental chair. Some of the considerations were though reflected latently on the reported researches. Few studies focused on aesthetics to considerably reduce anxiety-filled procedure and associated psychological stress, through stylish aesthetics, reduced noise, styling, shape, size, control, different color fabrics, upholstery, other tactile characteristics and narrow back design to improve workflow.[28] design of moon- like dental chair to conceal the elements of the design is typically aesthetic-driven. The technological and mechanical considerations were most studied utilizing numerical methodology and supported with robust finite element methodology (FEM) software. Structural analyses of the system were performed using finite element methodology.[12][29] utilized ANSYS and Solidworks respectively, to analyze stress, von Misses stress, distortion and factor of safety (FOS). The result of the analysis supported [29] in optimization of scissor link leg. Interestingly, the software applied by the researchers have exceptional capability of design –and- analyze, with no reported difference in performance.

It was observed that different types of materials were used in development of dental chair.[11] utilized wood in his design while [29] utilized mild carbon steel, to withstand mechanical and structural requirements of the operations. Improvements in material technology have reportedly led to proliferations of mechanically compliant and medically suitable materials to reduce risk of infections. [8] considerations of a working dental chair were baseline design factors and holds key to market competitiveness. Plethora of studies was carried out to study technology, ergonomics, economics and aesthetics either as a survey or scientific paper. The study designs of the survey papers were reportedly prospective, contextual and descriptive, while scientific studies were analytical, exploring various computational based- numerical methodologies.

III.   Conclusion

Scientific studies was predominant type of dental patient treatment chair study from 2010-2023. The

scientific studies were essential on design and development that were electricity based. Ninety – two of the studies focused on various technologies to recline and articulate dental chair. With numerical methodology and ever-evolving computational engineering tools, systems can be studied more precisely than ever, as identified in finite element-based analysis and other forms of simulations. Notably, finite element methodology- based graphical software utilized included Ansys and solidworks.

Compliance with Ethical Standards

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that supports the findings of this study are available on request from corresponding author

Disclosure of conflict of interest

The authors declare that there is no conflicts of interest

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