UPPER AIRWAYS MODELLING AND VALIDATION OF MANDIBULAR ADVANCEMENT SURGERY USING VARIABLE AIRFLOW AND THE EFFECT TO WALL SHEAR

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A thesis submitted
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2022

DECLARATION

I declare that this Choose an item. entitled "UPPER AIRWAYS MODELLING AND VALIDATION OF MANDIBULAR ADVANCEMENT SURGERY USING VARIABLE AIRFLOW AND THE EFFECT TO WALL SHEAR" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : MOHD NUR IMAN BIN MOHD SOFI

Date : 11 JANUARY 2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature	:	MOHD FARUQ BIN ABDUL LATIF Pensyarah Jabatan Teknologi Kejuruteraan Mekanikal Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan Universiti Teknikal Malaysia Melaka
Supervisor Name	:	Ts. MOHD FARUQ BIN ABDUL LATIF
Date	:	11 JANUARY 2023

DEDICATION

This project is dedicated to my parents who have never failed to give us financial and moral support, for teaching me that even the largest task can be accomplished if it is done one step as a time. I dedicate this Project to all the people who have worked hard to help us complete this project.

ABSTRACT

The pressure, velocity, and airflow characteristics of the human upper respiratory tract have been widely investigated, with a focus on the effect of geometric aspects. Model airflow characteristics and upper airway quality utilising a range of patient circumstances on geometric and operational settings that change because of the availability of contemporary computer hardware and software. For assessing upper airway airflow and preparing patients for surgery, computational fluid dynamics has emerged as a feasible technique. The objective of this project is to conduct a literature review on computational fluid dynamics methods and modelling for upper respiratory tract analyses. Utilization of experimental and computational methods in upper airway research. Physical experiment validation by comparing the experiment procedure. The upper airway flow is simulated using computational fluid dynamics. The simulation model must be tested to ensure that it functions as expected or replicates an actual event. Using clinical data to validate the upper respiratory tract biomechanical modelling model boosted user trust in computational fluid dynamics computations. In the computational fluid dynamics model validation process, experimental data or clinical data standards are commonly utilised to validate simulation results.

ABSTRAK

Ciri tekanan, halaju dan aliran udara saluran pernafasan atas manusia ada telah disiasat secara meluas, dengan tumpuan kepada kesan aspek geometri. Aliran udara model ciri dan kualiti saluran udara atas menggunakan pelbagai keadaan pesakit pada tetapan geometri dan operasi yang berubah kerana adanya kontemporari perkakasan dan perisian komputer. Untuk menilai aliran udara saluran udara atas dan menyediakan pesakit untuk pembedahan, dinamik bendalir pengiraan telah muncul sebagai teknik yang boleh dilaksanakan. Objektif projek ini adalah untuk menjalankan kajian literatur tentang dinamik bendalir pengiraan kaedah dan pemodelan untuk analisis saluran pernafasan atas. Penggunaan eksperimen dan kaedah pengiraan dalam penyelidikan saluran pernafasan atas. Pengesahan eksperimen fizikal oleh membandingkan prosedur eksperimen. Aliran saluran udara atas disimulasikan menggunakan pengiraan dinamik bendalir. Model simulasi mesti diuji untuk memastikan ia berfungsi seperti yang diharapkan atau mereplikasi peristiwa sebenar. Menggunakan data klinikal untuk mengesahkan bahagian atas model pemodelan biomekanikal saluran pernafasan meningkatkan kepercayaan pengguna terhadap bendalir pengiraan pengiraan dinamik. Dalam proses pengesahan model dinamik bendalir pengiraan, data eksperimen atau piawaian data klinikal biasanya digunakan untuk mengesahkan simulasi keputusan.

ACKNOWLEDGEMENTS

Firstly, First and foremost, I had like to thank my supervisor, Ts. Mohd Faruq Bin Abdul Latif, for his constant support of my Bachelor of Mechanical Engineering Technology (Honors) research and study, as well as his patience, encouragement, passion, and vast knowledge. His advice was vital during the research and writing of this thesis.

Next, my appreciation also goes to the School of Mechanical Engineering Technology, School of Engineering Technology for approving my project proposal for doing this modelling and validation of mandibular advancement surgery using variable airflow and the effect to wall shear. It is very interesting project to be done.

Finally, I must also express my gratitude to my parents and friends for the tremendous support and assistance they provided throughout the duration of this project. The completion of this project would have been extremely challenging without their assistance.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
CFD	-	Computational Fluid Dynamics
UA	-	Upper Airways
OSA	-	Obstructive Sleep Apnea
MAS	-	Mandibular Advancement Surgery
CT	-	Computerized Tomography
TKE	-	Turbulence Kinetic Energy
T	-	Temperature
SLS	-	Selective Laser Sintering

CHAPTER 1

INTRODUCTION

1.1 Background

The most prevalent form of breathing problem that occurs during sleep is called obstructive sleep apnea. During the night, it will cause you to continuously stop and start breathing for no apparent reason. There are various subtypes of sleep apnea, but obstructive sleep apnea is by far the most prevalent form. During sleep, you can develop this form of obstructive sleep apnea when the muscles in your throat occasionally relax and restrict your airway. Snoring is one of the most obvious symptoms of obstructive sleep apnea.

There are treatments for obstructive sleep apnea. One treatment option is a device that uses positive pressure to keep your airway open while you sleep. A mouthpiece that pushes your lower jaw forward while you sleep is another possibility. Surgery may also be a possibility in rare circumstances. Obstructive sleep apnea occurs when the muscles at the back of the throat relax too much to enable regular breathing to occur. In addition to uvula and tonsils, these muscles help to keep the tongue and soft palate at their proper positions in the rear of your mouth.

When you inhale, your muscles relax, narrowing or closing your airway for 10 seconds or more. A buildup of carbon dioxide and a consequent decrease in blood oxygen levels might result as a result. When your airway is clogged, your brain rouses you from sleep so that you may reopen it. Because this awakening is so brief, most people don't recall it.

While shortness of breath might jolt you out of a sound sleep, it is quickly alleviated with a few deep breaths. You may snort, choke, or gasp at some point. Five to thirty times or more an hour or more, all night long, this pattern may recur. You won't be able to reach the deep, restorative phases of sleep as a result of these disruptions, and you'll probably feel sleepy during the day.

People who suffer from obstructive sleep apnea may be unaware that their sleep is being disrupted. Many persons with this sort of sleep apnea are unaware that they haven't had enough sleep.

1.2 Problem Statement

Based on the final total article that have been search, several authors explain the experimental procedure. Aside from that, the physical validation model should be applied to a variety of scenarios, and a directory of data might be built from diverse cases due to the time required to wait for the results and data (Faizal *et al.*, 2020).

The results demonstrated that a decreased cross-sectional size of the airway increased airflow characteristics, especially when the lungs are working hard. During heavy breathing, the airway was found to be filled with turbulence. Turbulent kinetic energy, which exposes the behaviour and concentration of mean flow, can be used to estimate the severity of OSA. (Faizal *et al.*, 2021).

1.3 Research Objective

The main aim of this research is to estimate the upper airways modelling and validation of mandibular advancement surgery using variable airflow and the effect to wall shear. Specifically, the objectives are as follows:

a) To study the air pressure of UA

b) To study the impact variation of airflow velocity on the UA wall shear

c) To study the relation of wall shear with UA geometry

d) To develope validation methods for grid sensitivity analysis.

1.4 Project Scope

Provide a validation and computational fluid dynamics investigation on OSA resulting from mandibular advancement surgery with variable airflow and the effect on wall shear. In addition, the year range for articles is 2018 to 2022, to ensure that the data is relevant to the current situation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the course of doing this research project, a systematic literature review will be conducted. This ensures accurate data collection by excluding and analyzing any articles that are not directly related to the project. The SLR method is difficult and time-consuming, but it allows us to track the growth of our product in increments (Xiao and Watson, 2017).

2.2 Prisma Method

The PRISMA approach was utilised to locate the article for this study. This strategy will direct you in your search for the appropriate article. Also, a systematic review will conduct a comprehensive search of all published reports on the topic to answer a well-defined research question, selecting reports to include in the review based on numerous inclusion and exclusion criteria, and then synthesising the results.

Checklists and a four-phase flowchart are included in the PRISMA guidelines. The flowchart shows how to find, filter for, and include reports that meet the criteria for the review. There are 27 suggestions in the checklist, including topics like the title, abstract and introduction as well as results and discussion. Using this flowchart and checklist, PRISMA items serve as a guide for authors, reviewers, and editors (Selçuk, 2019).

2.2.1 Research Strategies

The first step in applying this process is to come up with alternative meanings for each of the words that are used in the title of the project. This stage is essential because it has the potential to result in a number of different meanings being assigned to each word. Utilizing Teasurus makes the process of discovering alternative words for each individual word much easier.

Table 1 Synonyms for each keywords

Keywords	Synonyms
Upper	Uppermost, Top, High
Airways	Air passage, Air shaft
Modelling	Create, Design, Mould
Validation	Acceptance, Proof
Mandibular (mandible)	Bone, Mouth
Advancement	Advance, Improvement
Surgery	Incision, Abscission
Obstructive	Antithetical, Conflicting
Apnea	Hiatus, Pause

2.2.2 Search String

Creating a search string is the next step in the process. A good and detailed search string can aid in locating the exact article that matches your title. An algorithm based on Visual Text Mining is used to help the researcher by suggesting more words to include in their string. Approaches like this aggregate important phrases from a researcher's selected studies and show them in a way that promotes visualization and helps the development and improvement of the search string (Mergel, Silveira and da Silva, 2015).

Table 2 Search string for the searching on website

Data	Search String
`Scopus	ALL (("obstructive sleep$ apnea" OR "obstructive sleep$ snore$" OR "sleep apnea") AND ("upper airway$" OR "uppermost airways$" OR "top airway$" OR "top air shaft" OR "top air passage") AND ("model$" OR "create$" OR "design$" OR "mold$") AND ("validation$" OR "acceptance$") AND ("mandibular" OR "bone" OR "mouth") AND ("advance$" OR "improvement") AND ("surgery" OR "incision" OR "abscission") AND ("airflow" OR "air" OR "ventilation") AND ("wall shear"))
Science Direct	Obstructive Sleep Apnea Upper Airways Modelling and Validation of Mandibular Advancement Surgery using variable airflow and the effect to wall shear.

2.2.3 Flow Diagram

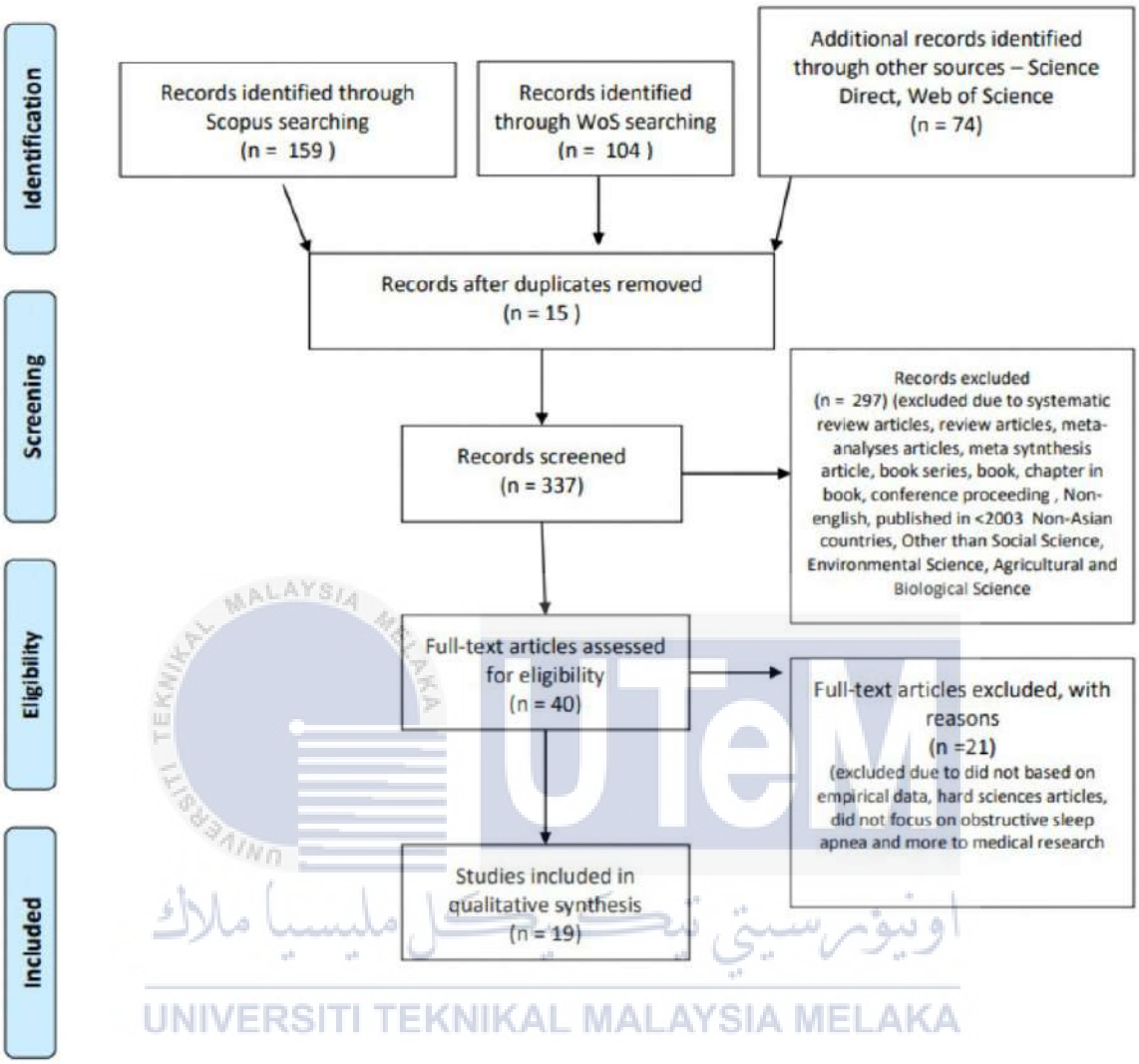

Figure 1 Flow diagram process for searching article

The identifying process involved using the search string that had previously been developed to search the article in the chosen article page. The university has recently acquired a number of websites that will be of assistance to us in our search for information and downloading articles from the internet. The total number of article that have been search from the 3 websites is 337 articles.

Another step in the research process is screening. This step necessitated the exclusion of everything but the papers below from 2018, as well as systematic reviews and meta-analyses and Meta-synthesizes in books and book chapters. For the eligibility procedure, it is an article that we have full access to, as well as those that have undergone some final review. This is to exclude hard scientific and non-obstructive sleep apnea-related items. There will be a total of 19 articles utilized for references and citations. This essay will serve as a guide for us to complete our research.

2.3 Advancement of Study

This subtopic will concentrate much of its attention on our completed pieces of study. The experimental and computational processes that have been carried out will be broken down in further detail in the next section. In addition, discuss each publication's research methods and findings.

2.4 Fishbone

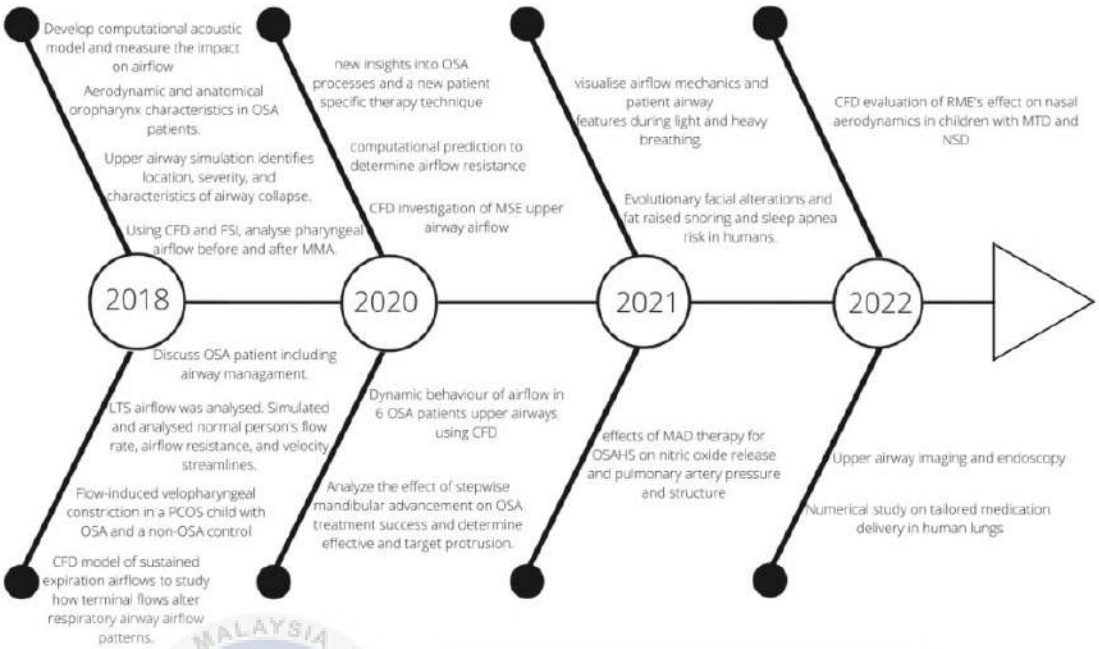

Figure 2 Fishone diagram with all the articles

Using a Fishbone diagram, one may look at the relationships between consequences and the underlying factors that lead to or exacerbate those effects. Because of its purpose, the Fishbone diagram is often known as a cause-and-effect diagram. The structure of the graphic is evocative of the skeleton of a fish. In order to have a more full view of the causes and sub-causes, it may be necessary to include qualitative and quantitative risk ratings of the causes and sub-causes, along with their names and codes (Ilie and Ciocoiu, 2010).

2.5 Validation

To put it another way, validity is the degree to which a method accurately assesses what it claims to. When a study has a high degree of validity, the findings are correlated to real-world qualities, characteristics, and variations. When a measurement is very reliable, it provides proof that it is trustworthy. This paper's contribution is that it examines several forms of validation using examples from studies, evaluates the problems that were identified as relevant, and describes how they were handled in each instance (Gunnar and M., 2010).