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Accelerated Chronic Wound Healing Through Percussive Oxygen Flow and Continuous Oxygen changes in a Pressurized Chamber

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Abstract: ***Diabetic foot ulcers and gangrenous wounds remain a major clinical challenge due to impaired perfusion, tissue hypoxia, infection, and delayed healing. Even after surgical intervention such as amputation, residual wounds often show poor granulation and prolonged healing because of compromised microcirculation and reduced local oxygen availability. This abstract presents a novel wound healing approach using continuous oxygen changes within a pressurized chamber, applied in the post-amputation setting for diabetic foot gangrene. Unlike intermittent or static oxygen delivery methods, this system provides a continuous flow of oxygen with controlled pressurization, enabling constant renewal of oxygen concentration at the wound interface and these changes help overcome diffusion limitations commonly seen in diabetic and ischemic tissues. This dynamic oxygen environment enhances diffusion into hypoxic tissues, maintains a favorable wound pO_2 gradient, and supports key physiological processes including angiogenesis, fibroblast proliferation, collagen synthesis, and bacterial load reduction. The pressurized chamber further enhances oxygen penetration into wound tissues while helping to reduce edema and bacterial burden. We report the case of a 54-year-old male with type 2 diabetes mellitus who developed ischemic diabetic foot gangrene involving the first toe. Following surgical amputation, a pressurized chamber delivering percussive oxygen flow with continuous oxygen changes was applied to the wound site to accelerate granulation tissue formation, enhance wound bed preparation, and minimize the risk of secondary infection and delayed closure. The continuous flow of oxygen under controlled pressurization enables constant renewal of oxygen concentration at the wound interface, thereby addressing one of the major pathophysiological challenges in diabetic wound healing— chronic tissue hypoxia. This novel continuous oxygen therapy represents a promising adjunctive treatment for complex diabetic foot ulcers and post-amputation wounds, with the potential to improve healing outcomes, reduce complications, and shorten overall recovery time.***

Keywords: Diabetic foot ulcer, Topical oxygen therapy, Pressurised oxygen chamber, Tissue oxygenation, wound healing

I. INTRODUCTION

Diabetic foot ulcers (DFUs) and gangrenous wounds represent a significant and growing healthcare burden worldwide, particularly among patients with long-standing diabetes mellitus. These wounds are notoriously difficult to manage due to a combination of pathological factors, including impaired microcirculation, peripheral vascular disease, neuropathy, persistent infection, and chronic tissue hypoxia. Even after necessary surgical interventions such as debridement or amputation, post-operative wounds often exhibit delayed healing, poor granulation tissue formation, and an increased risk of secondary infections, ultimately leading to prolonged morbidity and higher healthcare costs.

A critical factor underlying impaired wound healing in diabetic patients is reduced oxygen availability at the tissue level. Oxygen plays a vital role in cellular metabolism and wound repair processes, including angiogenesis, collagen synthesis, fibroblast proliferation, and immune defense. However, in ischemic and diabetic tissues, oxygen diffusion is limited, rendering conventional wound care and oxygen therapies less effective. Existing oxygen delivery methods like static oxygen therapies, often fail to maintain a consistent and adequate oxygen gradient at the wound interface.

In response to these challenges, innovative therapeutic strategies are needed to enhance tissue oxygenation in a more efficient and sustained manner.

The present study introduces a novel approach utilizing percussive oxygen flow with continuous oxygen changes within a pressurized chamber to improve wound healing outcomes. Unlike traditional static oxygen delivery systems, this technique provides a dynamic and continuously renewed oxygen environment under controlled pressurization. It also eliminates passive gases like CO_2 and moisture, such a system aims to overcome diffusion limitations, enhance oxygen penetration into hypoxic tissues, and create a favorable microenvironment for accelerated wound repair.

By maintaining a stable and elevated partial pressure of oxygen (pO_2) at the wound site, this method has the potential to significantly improve critical healing mechanisms, including neovascularization, collagen deposition, bacterial control, and edema reduction. Applied in the post-amputation setting for diabetic foot gangrene, this approach may offer a promising adjunct to conventional wound care, ultimately reducing healing time, minimizing complications, and improving overall patient outcomes.

This study explores the application and therapeutic potential of continuous oxygen flow within a pressurized chamber in a diabetic patient following toe amputation, highlighting its role in addressing one of the key barriers to healing—chronic tissue hypoxia.

II. LITERATURE REVIEW

Diabetic foot ulcers (DFUs) represent a major global health challenge and are among the most severe complications of diabetes mellitus. Their incidence continues to rise due to increasing prevalence of diabetes, obesity, and aging populations. DFUs are associated with significant morbidity, high healthcare costs, and an increased risk of hospitalization and amputation [1]. Chronic diabetic wounds are characterized by persistent inflammation, impaired angiogenesis, extracellular matrix degradation, and delayed epithelialization. The pathophysiology is multifactorial, involving neuropathy, microvascular dysfunction, infection, and impaired immune response. A key contributing factor in these wounds is chronic tissue hypoxia, resulting from compromised oxygen delivery and poor perfusion [2] [3]. Oxygen tension in chronic wounds is often significantly reduced, impairing cellular activity and delaying the progression through the normal phases of wound healing. Prolonged hypoxia disrupts tissue repair processes, leading to non-healing wounds and increased risk of infection and amputation [4].

A. Role of Oxygen in Wound Healing

Oxygen plays a vital role in cellular metabolism and is essential for several physiological processes involved in wound repair. These include collagen synthesis, fibroblast proliferation, angiogenesis, epithelialization, and bacterial killing via oxidative mechanisms [5].

Adequate oxygen availability is critical for hydroxylation reactions required for collagen formation and for ATP production during cellular proliferation. In diabetic wounds, reduced oxygen levels impair fibroblast function, collagen deposition, and immune response, thereby prolonging inflammation and delaying healing [6].

Although transient hypoxia may initiate signalling pathways through hypoxia-inducible factors (HIFs), sustained hypoxia negatively affects wound healing outcomes. Chronic wounds remain in an inflammatory state and fail to transition effectively into proliferative and remodelling phases [7].

B. Oxygen-Based Therapies for Wound Management

1) Hyperbaric Oxygen Therapy (HBOT)

Hyperbaric oxygen therapy (HBOT) delivers 100% oxygen under increased atmospheric pressure, enhancing oxygen dissolution in plasma and facilitating diffusion into hypoxic tissue. Evidence from multiple systematic reviews suggests that HBOT may improve wound healing and reduce major amputation rates in selected patients with diabetic foot ulcers.

Additionally, variability in patient selection, treatment protocols, and outcome measures has led to conflicting conclusions regarding its effectiveness. However, HBOT is associated with several limitations, including high cost, limited accessibility, need for specialized facilities, and inconsistent impact on amputation rates. These factors restrict its widespread clinical application.

2) Topical Oxygen Therapy (TOT)

Topical oxygen therapy (TOT) delivers oxygen directly to the wound surface under localized conditions. It has been used clinically for several decades and has shown promising outcomes in chronic wound management.

Systematic reviews and meta-analyses indicate that TOT:

- Significantly increases wound healing rates
- Reduces wound size
- Enhances tissue oxygenation [8]

Despite its advantages, conventional TOT systems may be limited by inadequate oxygen penetration, inconsistent delivery, and inability to sustain optimal oxygen gradients within the wound bed.

3) Continuous Diffusion of Oxygen Therapy (CDOT)

Continuous diffusion of oxygen therapy (CDOT) represents an advancement over traditional oxygen therapies by providing a continuous and controlled oxygen supply to the wound.

A randomized controlled trial demonstrated that CDOT significantly improved healing outcomes, with higher ulcer closure rates compared to standard therapy (46% vs 22%) and faster wound healing [9].

Additional studies have shown that combining CDOT with conventional wound care:

- Enhances wound healing rates
- Reduces inflammatory markers
- Decreases amputation risk [10]

Recent reviews also indicate that CDOT is clinically effective and may be cost-effective for managing chronic, non-healing DFUs [11].

C. Limitations of Existing Oxygen Therapies

Despite demonstrated benefits, current oxygen therapies face several limitations:

- Restricted diffusion into deep ischemic tissues
- Inconsistent oxygen delivery and transient exposure
- Inability to maintain stable oxygen partial pressure (pO_2)
- Influence of wound exudate and environmental factors

These limitations highlight the need for more efficient oxygen delivery systems capable of providing sustained and controlled oxygenation in chronic wounds.\

D. Rationale for Percussive Oxygen Flow in a Pressurized Chamber

Given the limitations of existing therapies, a system that integrates percussive oxygen flow with a pressurized wound environment offers a promising alternative.

Such an approach may provide:

- Enhanced oxygen diffusion into deeper tissues through pressure gradients
- Maintenance of elevated and stable pO_2 levels
- Improved removal of waste gases such as CO_2 and excess moisture
- Creation of an optimal microenvironment for tissue regeneration

Percussive oxygenation has been identified as a crucial factor for improving wound healing outcomes, particularly in chronic and ischemic conditions.

III.METHODOLOGY

Despite advances in wound care management, chronic wounds continue to represent a major clinical challenge due to persistent tissue hypoxia, impaired angiogenesis, reduced collagen synthesis, and increased susceptibility to infection. While conventional oxygen therapies have demonstrated potential benefits, their effectiveness is often limited by inadequate oxygen penetration, inconsistent oxygen gradients, and the accumulation of carbon dioxide and moisture around the wound surface. These limitations can restrict oxygen diffusion into ischemic tissues and hinder the healing process, particularly in post-amputation diabetic wounds where oxygen demand is substantially increased.

To address these challenges, a novel oxygen delivery system was developed based on the principle of percussive oxygen flow within a controlled pressurized chamber. The system was designed to provide a dynamic oxygen-rich environment capable of maintaining elevated oxygen partial pressure (pO_2) at the wound interface while continuously replacing depleted gases and excess moisture. Unlike conventional oxygen delivery methods, the proposed device promotes sustained oxygen availability through continuous gas exchange and pressure-assisted oxygen diffusion, thereby enhancing oxygen transport to hypoxic tissues.

The design objective was to create a therapeutic microenvironment that supports key wound healing processes, including neovascularization, fibroblast proliferation, collagen deposition, bacterial suppression, and edema reduction. The following section describes the design, operating mechanism, and clinical application of the developed device in the management of a diabetic post-amputation wound.

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A. Device Design

A novel oxygen therapy system was developed to provide percussive oxygen flow within a closed pressurized chamber designed specifically for wound management. The system consists of four primary components: (1) Percussive flow generator, (2) a transparent chamber with breathable medium, (3) a concentrated oxygen source (external), and (4) Tubing.

The oxygen source supplies high-purity oxygen to the percussive flow generator. This device generates percussive flow pattern in which oxygen is delivered as pressurised bolus and creates a dynamic oxygen environment around the wound surface, continuously replenishing oxygen at the tissue interface. Device have pressure display and control to monitor pressure levels are within the limits. The pressurising chamber is constructed from biocompatible, airtight materials capable of maintaining a controlled pressure environment. The chamber is designed to wrap around the wound area and allowed to breath the oxygen. Simultaneously, the system incorporates a continuous exhaust outlet that removes passive gases generated within the chamber. This continuous gas replacement mechanism prevents oxygen depletion and maintains a stable oxygen-rich microenvironment conducive to wound healing.

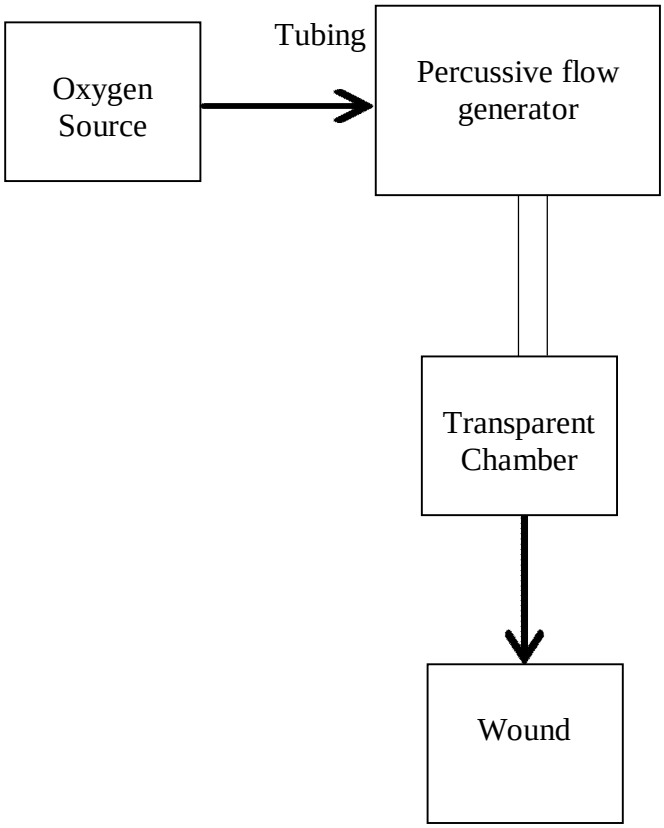

Fig. 1 A sample flow diagram of proposed system

B. Experimental Setup

1) Background

Diabetic foot ulcers and gangrenous wounds are difficult to heal due to impaired microcirculation, chronic tissue hypoxia, increased infection risk, and reduced cellular response. Even after surgical amputation, post-operative wounds often show delayed granulation and prolonged healing. Oxygen plays a critical role in angiogenesis, collagen synthesis, fibroblast proliferation, and bacterial control. However, conventional oxygen delivery methods—both topical and systemic—are often intermittent or insufficient to overcome diffusion limitations in ischemic diabetic tissues. Impaired vascular supply further restricts effective oxygen transport to the wound bed, limiting the healing potential despite adequate systemic oxygen levels.

2) Objectives

To evaluate the clinical effectiveness of continuous oxygen changes within a pressurized chamber for improving wound healing outcomes in diabetic foot gangrene.

3) Method

A severe wound as in Fig.2, where all the conventional methods failed to heal is analysed as in Fig.3. After completing standard wound assessment and performing appropriate debridement, the wound was taken to the experimental setup as in Fig.4. Wound was enclosed within a transparent chamber with breathable medium. Medical oxygen was delivered using a percussive flow generator (ncore oxygen therapy system), which creates a percussive flow throughout the therapy session and facilitates passive gas exchange, achieving approximately 30 oxygen changes per hour. The percussive flow generator is designed to enhance the energy and partial pressure of oxygen inside the chamber, promoting deeper oxygen penetration into the interstitial fluid and hypoxic tissues. The passive gas exchange mechanism within the chamber continuously removes contaminated gases, including small amounts of carbon dioxide and moisture produced during tissue metabolism. This therapy is administered for 1.5 hours daily over a period of 14 days.

Fig. 2 Initial image before starting therapy

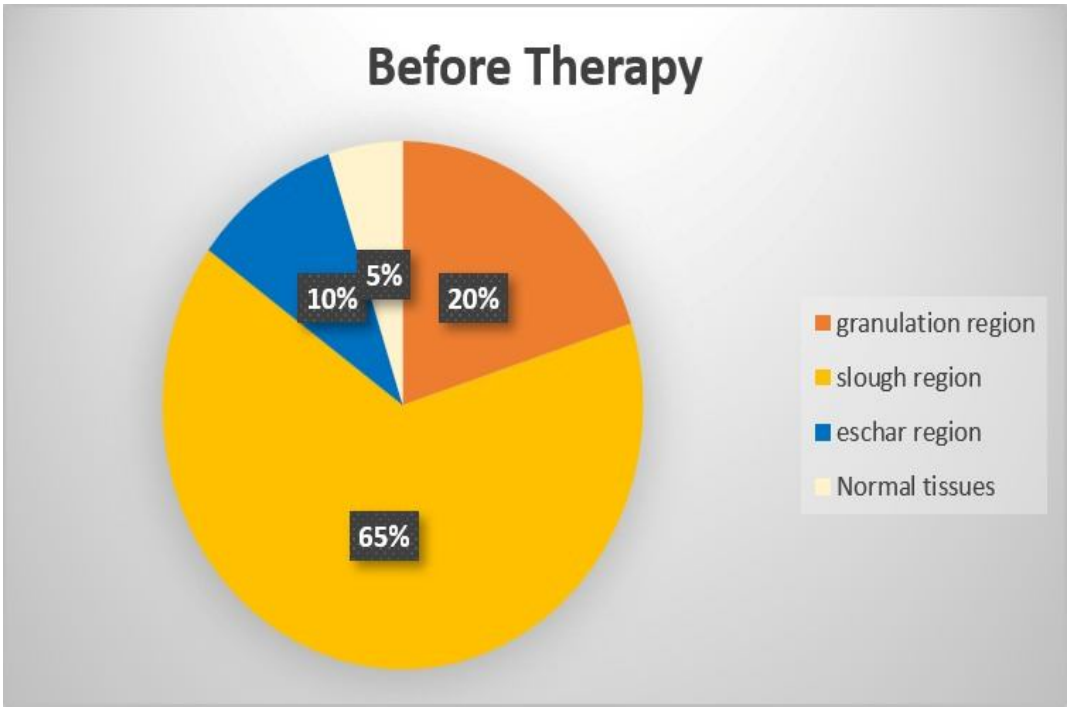

Fig. 3 Initial wound analysis before therapy (from woundtele.ai application)

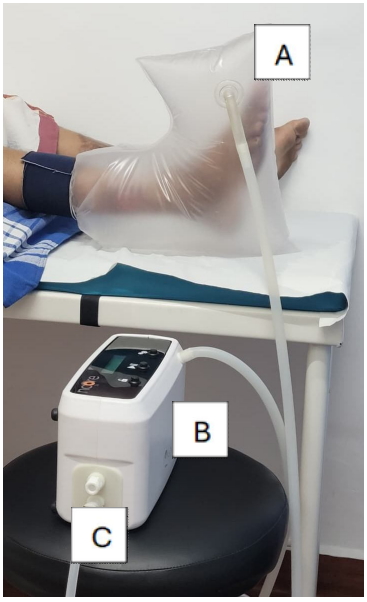

Fig. 4 Experimental setup for the therapy with A is the transparent chamber with breathable medium, B is the percussive flow generator, C is the tubing connected from external oxygen source to the percussive flow generator.

4) Results and findings

A 54-year-old male with type 2 diabetes mellitus presented with ischemic diabetic foot gangrene complicated by sepsis. He was status post (S/P) great toe amputation and had been referred from an external healthcare facility for consideration of major lower limb amputation. We started intravenous antibiotics, followed by extensive surgical debridement to control infection and remove non-viable tissue. Post-debridement, continuous oxygen therapy was administered in a pressurized chamber to enhance local tissue oxygenation and support wound healing. This combined therapeutic approach resulted in successful limb salvage, with preservation of the remaining foot and toes. We have continuously monitored the healing pattern after 20 days visually as in Fig.5 and it is analysed as in Fig.6.

Fig. 5 Image after 20 days of therapy

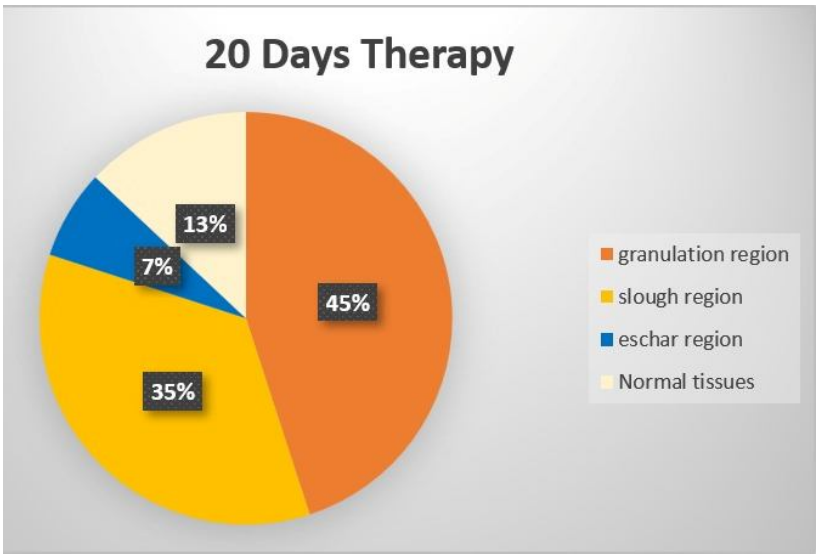

Fig. 6 Analysis after 20 days of therapy (from woundtele.ai application)

Similar study was conducted after 45 days as shown in Fig.7 and analysis in Fig.8.

Fig. 7 Image after 20 days of therapy

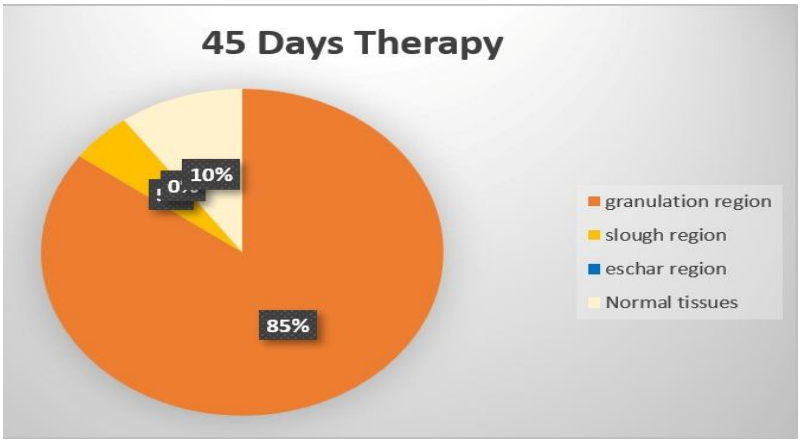

Fig. 8 Analysis after 20 days of therapy (from woundtele.ai application)

The treatment facilitated early and robust granulation tissue formation, improved wound bed quality, reduced edema, and minimized the risk of secondary infection. The wound demonstrated steady progression without complications, reflecting optimization of the local healing microenvironment. Drastic reduction in wound size as in Fig.9 were noticed. And also, CRP levels were also dropping faster, considered as too low infection indication as in Fig.10.

Fig. 9 A sample graph showing reduction in wound area

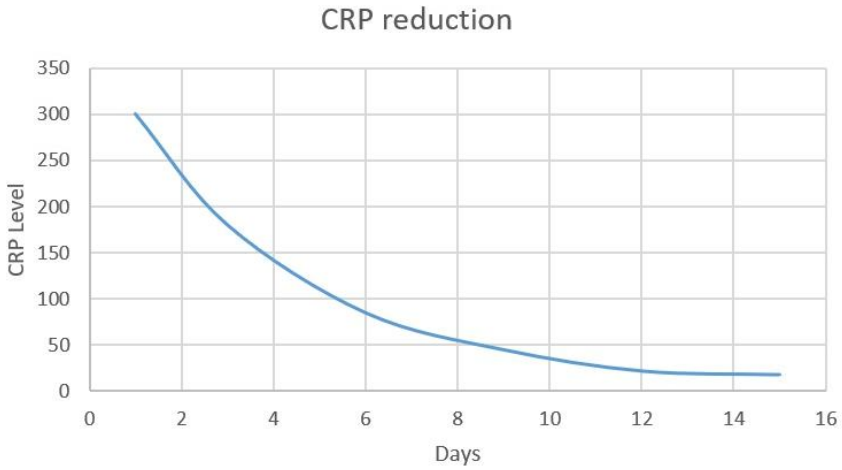

Fig. 10 A sample graph showing reduction in CRP level

IV. CONCLUSIONS

Percussive oxygen therapy delivered within a transparent chamber containing a breathable medium represents a promising adjunctive treatment strategy for the management of post-amputation diabetic foot wounds. Diabetic patients frequently experience impaired wound healing due to chronic tissue hypoxia, microvascular dysfunction, reduced cellular activity, and a heightened risk of infection. By providing controlled oxygen directly to the wound environment, percussive oxygen therapy may help overcome these physiological limitations and create conditions that are more favorable for tissue repair.

The enhanced availability of oxygen supports several critical phases of wound healing, including fibroblast proliferation, collagen synthesis, angiogenesis, and epithelialization. In addition, adequate oxygenation can improve local immune function, facilitate bacterial clearance and reduce the likelihood of wound-related complications. The percussive delivery mechanism may further enhance oxygen diffusion into compromised tissues, thereby improving perfusion and stimulating cellular responses necessary for regeneration.

The use of a transparent treatment chamber with breathable medium eliminates the stagnant oxygen and make fresh oxygen environment. This approach may be particularly beneficial for patients with complex diabetic and ischemic wounds, where delayed healing often leads to prolonged hospitalization, recurrent infections, and an increased risk of further amputation.

V. ACKNOWLEDGMENT

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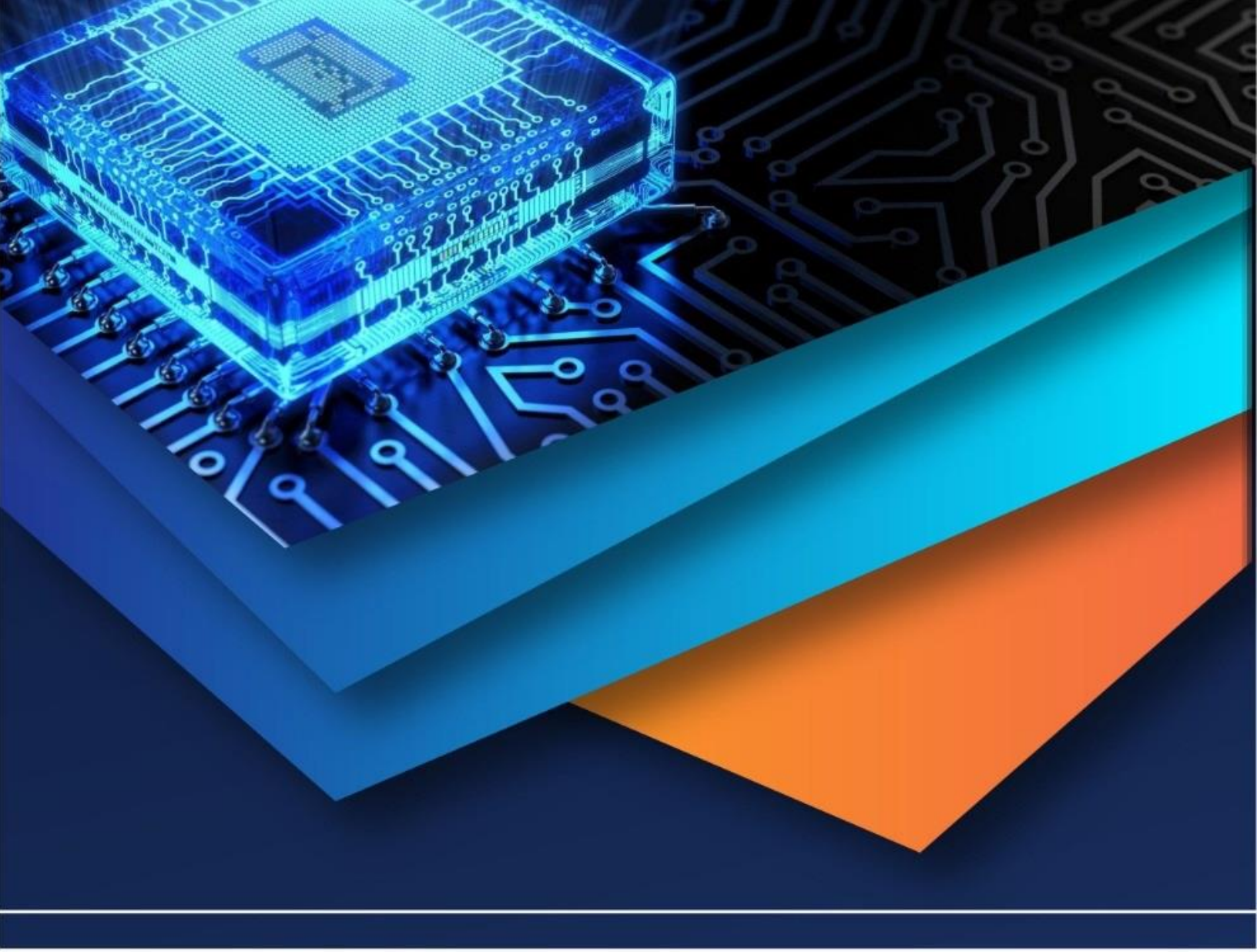

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