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Restrictions on Consonant Sequencing in Arabic Triliteral Roots

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ABSTRACT

Consonant sequences in first and second position (C1C2) in Arabic triliteral roots (C1C2C3) were investigated to determine which consonants occur in C1 and C2 positions. The study also examed whether phonetic features, such as place of articulation, manner of articulation, and voice impose co-occurrence restrictions on C1C2 sequences within the root, and whether these restrictions are gradient or categorical. To that end, a total of 4,738 Arabic triliteral roots were extracted from two well-established Arabic-Arabic dictionaries; *Assihah and Al-Ayn* dictionaries and investigated. This study is grounded in the general synchronic (descriptive) theory of phonology which investigates sounds and their behavior at a specific stage during the development of a language with an eye on the gradient harmony of adjacent root consonants as modeled by the harmonic model of linguistic well-formedness. Roots were extracted and grouped alphabetically according to the quality of the consonant in C1 position. Then phonetic variations of the C2 consonant were compared with those of C1. Percentages of these co-occurrences were calculated and classified in tables. The data analysis showed more symmetrical restrictions on C1C2 sequences in relation to place of articulation compared to manner of articulation and voicing which had a minor role in restricting consonants co-occurrences. These restrictions were found to be gradient rather than categorical. More similarities between the consonants imposed more restriction on their occurrence in root sequences.

Keywords: Phonotactics; Consonant Sequence; Place of Articulation; Manner of Articulation; Voicing

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1. Introduction

Arabic has a rich consonantal system and a limited number of vowels[1]. Watson argues that the sound system of Arabic is similar to other Semitic languages[1]. Investigating an aspect related to the sound system of one language may, to a certain extent, be generalized to other Semitic languages. Many Arabic consonants are absent in English and other Indo-European languages. These consonants include the pharyngeal sounds /ħ/ ([ح]) and /ʕ/ ([ع]), produced by moving the root of the tongue towards the pharynx, as well as the uvular stop /q/ ([ق]) and the velar fricatives /x/ ([خ]) and /ɣ/ ([غ])[2]. Levantine Arabic (LA), spoken in Syria, Lebanon, Jordan, and Palestine, exhibits some variations, such as the frequent lenition of /q/ to the glottal stop /ʔ/ in urban dialects[3]. Like other Arabic varieties, LA also employs emphatic consonants (/sˤ/, /dˤ/, /tˤ/, /ðˤ/), though their phonetic realization may differ slightly due to regional influences[4]. These phonetic contrasts are crucial to Arabic phonology and contribute to its complexity.

The vowel system in Arabic, on the other hand, is simpler than its consonantal system, typically consisting of three short vowels (/a/, /i/, /u/) and their long counterparts (/aː/, /iː/, /uː/)[5]. In Levantine Arabic, vowel quality is heavily influenced by neighboring consonants, particularly emphatics, which trigger lowering and retraction[6]. Additionally, LA exhibits vowel reduction in unstressed syllables, with short /i/ and /u/ often merging into a schwa /ə/[7]. These variations highlight the dynamic interaction between consonants and vowels in shaping Arabic phonetics.

Prosodic features such as stress and intonation also play a significant role in Arabic, with Levantine Arabic displaying distinct patterns. Stress is generally predictable but may shift due to syllable structure or morphological factors[8]. LA intonation is marked by a wider pitch range compared to other dialects, with rising contours often signaling questions or emphasis[9]. The phonetic complexity of Arabic, from its consonant inventory to its suprasegmental features, makes it a compelling area of study while presenting unique challenges for learners[10].

According to *Assihah* dictionary (2008), Modern Standard Arabic (MSA) has 5,778 roots, most of which are composed of three consonants. There are (4738) triliteral roots, (853) quadrilateral roots, and (187) of pentalateral roots in Arabic representing 82%, 14.8%, and 3.2% respectively. Triliteral roots clearly make up the biggest portion among other types of roots, but this doesn't mean that it is possible for any pair of consonants to occur adjacently. Identical consonant sequences are impossible in C1C2 position, and not all other consonant sequences are equally permissible in these roots. This raises the question: "What restrictions hold, and why?"

The literature on various aspects of Arabic linguistics abounds. Some general discussions related to different aspects of MSA such as phonology, morphology, syntax, sociolinguistics...etc. target learners of Arabic with emphasis on learning MSA[11]. Structures, functions and varieties of Arabic and their lexical and stylistic development were also investigated[5]. Perceptual reports in dialects of Arabic focusing on Modern Standard Arabic and Maltese were also under scrutiny[12]. Arabic diacritization using Hidden Markov Models (HMMs) was the focus of research as well[13]. The performance of the proposed system was assessed using a data corpus that includes more than 24,000 sentences. Diacritization is also discussed with reference to the rule-based method, statistical method, and hybrid method[14–17].

Morphological investigations of Arabic focus on whether the unit underlying lexical access and representation is the phonetic word or the morpheme[18–20]. Morphological units in the Arabic mental lexicon were investigated to find whether the mental lexicon of MSA speakers is morphologically structured and whether the three-consonantal root is the correct basic unit underlying lexical processing and representation in MSA[21]. The factors affecting the acquisition of plural morphology in Jordanian Arabic were also investigated[22]. The study investigates the development of plural morphology in Jordanian Arab children, and explores the roles of the predictability, transparency, productivity, and frequency of different plural forms in determining the stages that children follow in acquiring the plural morphological system. The study also re-examines the development of the notion of default over several years.

Different aspects of the phonology and morphology of Arabic varieties have been discussed[1]. The Cairene and San'ani phoneme systems have been investigated compared to MSA showing that the San'ani consonantal system is much closer to MSA.

Consonant sequences in Arabic have been studied from various linguistic perspectives, including phonology, mor-

phology, psycholinguistics, and language acquisition. Arabic, as a Semitic language, exhibits complex consonant clustering due to its non-concatenative morphology, where roots typically consist of three consonants (CCC) interleaved with vowels to form words. Research has explored topics such as syllable structure constraints, sonority hierarchy, phonotactic rules, and the processing of consonant clusters by native and non-native speakers. Arabic phonotactics restrict certain consonant sequences, particularly in syllable onsets and codas. Complex clusters often undergo epenthesis (vowel insertion) or deletion to comply with syllable structure rules. Studies have examined how Modern Standard Arabic (MSA) and dialects handle these constraints differently [1,23–25].

The root-system of Arabic has been examined in terms of phonology, morphology, syntax... However, none of the previous studies has examined co-occurrence restrictions of all triliteral roots of Modern Standard Arabic in terms of place of articulation, manner of articulation, and voicing. Therefore, this study provides a step towards filling the gap in the literature from this aspect.

Verbal roots containing homorganic consonant pairs are rare in Arabic, and this phenomenon motivates the existence of an OCP-Place constraint (Obligatory Contour Principle on place of articulation) in the phonological grammar [26]. They use an online lexicon of Arabic roots in order to explore the OCP constraint. They propose that the strength of the constraint is determined by the O/E ratio, which represents the observed number of examples of each consonant pair to the number that would be statistically expected under a random combination of phonemes.

Restrictions on place co-occurrence in Muna and Arabic were investigated [27]. The study concludes that place of articulation plays a vital role in determining which consonants may occur in (C1C2) positions in Muna and Arabic and speakers of the two languages have knowledge of these gradient place restrictions [27]. This leads us to assume that some consonants are blocked from being adjacent assumingly because of their phonetic features. Place of articulation, manner of articulation, and voicing are the three features which will be used to examine the hypothesis. Triliteral roots were selected to be examined simply because they represent the majority of roots. In addition, the study aims at finding if the presence of a feature in C1 for example prefers certain consonants to occur adjacent to it. In other words, what possible consonants typically occur in the C2 when C1 is a sonorant, coronal, or bilabial?

The study aims to answer three basic research questions.

1. Which consonants occur in C1 and C2 positions in Arabic triliteral roots, and how many roots are found with each consonant?
2. What phonetic features restrict the co-occurrence of consonants in C1C2 position?
3. Are these restrictions gradient or categorical?

Answering these questions will lead us to gradually provide general statements related to constrains against adjacency of consonants in triliteral roots in MSA. These observations may then be formulated into a theory that accounts for the restrictions in triliteral roots and then applied to the other types of roots. This work will also help researchers working on other Semitic languages' sound systems.

2. Methodology

2.1. Data Collection and Data Analysis

A total of 4,738 triliteral roots were collected from two major references in Arabic which are *Assihah* and *Al-Ayn* dictionaries. *Assihah* dictionary (2008) is a well-regarded Arabic-Arabic dictionary designed for students and advanced learners. It focuses on Modern Standard Arabic (MSA) while also including some colloquial terms, making it useful for both formal and informal contexts. Entries are listed by their root letters and provide concise meanings along with example sentences, helping users understand word usage in context. Some entries also include explanations of idiomatic expressions and cultural references.

Kitaab al-Ayn, compiled by the legendary Arab lexicographer Al-Khalil ibn Aḥmad al-Faraahiidi (d. 786CE), is the oldest known Arabic dictionary and a foundational work in Arabic linguistics. Unlike modern dictionaries, it follows a unique phonetic arrangement based on the articulation point of letters, starting with the deepest throat sound (ayn, [ع]) and progressing outward. It organizes words by triliteral roots, a structure still used in Arabic dictionaries today [28,29].

After triliteral roots were collected, they were ordered alphabetically. Triliteral roots are analyzed into pairs of consonants as (C1C2). Then, we calculated consonants that are

adjacent in the pairs (C1C2) by extracting the sequences and counting them. Percentages were calculated to show which consonants, if any, are preferred in (C1C2) sequences and what determines this preference (place of articulation, manner of articulation, or voicing). In this paper, we are only concerned with stating percentages of distributional patterns. Further investigations may seek more complex investigations with a comparative baseline to objectively measure whether results obtained are linguistically motivated or merely ungrounded distributional patterns.

2.2. Theoretical Background

This study adopts the descriptive theory of phonological analysis. Linguists have proposed a number of approaches to classify segments in the sound system in terms of their features[30–32]. A frequently referred to model of features is briefly outlined as: First, Major class features that include: Consonantal vs. non-consonantal, Syllabic vs. non-syllabic, and Sonorant vs. Non-sonorant. Second, cavity features which consist of Coronal vs. non-coronal, Anterior vs. non-anterior, Labial vs. non-labial, and Distributed vs. non-distributed. Then, Tongue body features represented mainly by High vs. non-high, Low vs. non-low, Back vs. non-back and velar suction vs. non-velar suction. Tongue root features that are advanced tongue root vs. Non-advanced tongue root, and Tense vs. Lax. Laryngeal features which consist of Spread glottis vs. non-spread glottis, constricted glottis vs. non-constricted glottis, and voiced vs. non-voiced. Manner of articulation features which involve the features of continuant vs. non- continuant, Nasal vs. non-nasal, Lateral vs. non-lateral, Strident vs. non-strident and Delayed release vs. instantaneous release. Finally, prosodic features that reflect long vs. short, Stress [+/- stress), and Tone[32].

The features that will be used in the present study are place of articulation, manner of articulation, and voicing with their minor representations as suggested by the Jakobsonian model as follows:

1. Cavity features refer to place of articulation, which indicates the point where the airstream is obstructed in the vocal tract during the production of sounds. When a sound is produced by raising the blade of the tongue towards the front teeth, the alveolar ridge, or the hard palate, it is then coronal. The feature [+] Coronal refers to sounds that are dental, alveolar, alveo-palatal, retroflex, and palatal. All other sounds are [-] coronal. The second cavity (or place of articulation) feature is [+/-] anterior. Sounds produced by the obstruction of the airstream that occurs at a point not farther back in the mouth than the alveolar ridge are [+] anterior. Anterior sounds are labials, dentals, and alveolars. Another cavity feature is [+/-] labial, sounds that are [+] labial are those produced by narrowing made with the lips. Labials include bilabial and labiodentals consonants, as well as rounded vowels. All other sounds are non-labials '[-] labial'. The last cavity feature represents sounds that are made with an obstruction of the airstream along the middle-line of the oral tract whereas non-distributed sounds are made with smaller area of contact between articulators. This feature is mainly used to distinguish apical from laminal sounds. If the tip of the tongue makes contact with front teeth, alveolar, or alveo-palatal the sounds produced are Apical while Laminal sounds are produced by the contact made with the blade of the tongue with the same areas which are alveolar, alveo-palatal, or front teeth.
2. Manner of articulation features describe the way in which the airstream is obstructed in the process of sounds production. When the sound is produced in a continuous, not completely, blocking the flow air through the glottis, pharynx it is continuant. All sounds are [+] continuant but affricates, nasals, oral stops, and laterals are [-] continuant. The second feature is lateral. Lateral sounds are produced when the air flow escapes from one or both sides of the tongue. Unlike laterals, Non-lateral sounds are produced when the air flow escapes through the center of the mouth. "l" sound is [+] lateral, other sounds are [-] lateral 'non-lateral'. Sounds that are produced by raising the velum so the air escapes through nasal cavity are nasal sounds'[+] nasal, but if sounds are produced through the oral cavity they are oral sounds '[-] nasal'. Nasal sounds include nasal stops like [m. n, and ŋ], as well as nasalized consonants, glides and vowels. Another manner feature is [+/-] strident. Strident sounds are produced with more random noise than non-strident sounds '[-] strident'. Strident feature, unlike other features that are defined in articulatory terms, is defined acoustically. The feature

strident distinguishes fricatives which have a highly pitched strident noise. Strident sounds include sibilants [s, z, ʃ, ʤ, tʃ, ʤ] and non-sibilants [f, v]. The last manner feature is delayed release which can only be applied to sounds produced in oral cavity. The delayed release feature distinguishes between stops 'plosives' from affricates in the way that stops are produced by suddenly releasing the closure whereas the closure is released gradually in affricates. All affricates are [+] delayed release and all other sounds are [-] delayed release 'instantaneous release'.

3. Voice value is included under the Laryngeal features. The production of Voiced sounds involves the vibration of the vocal cords. [- voice] sounds mostly known as 'voiceless sounds' are produced without such vibration. Voiced sounds include vowels, glides, liquids, nasals, and [b, d, g, v, ð, z].

This research is grounded in the general synchronic (descriptive) theory of phonology, which investigates sounds at a specific stage of the development of a language in order to analyze the sound patterns that occur. The research approaches sound classifications in the Arabic triliteral root system with an eye on the gradient harmony of adjacent root consonants as modeled by the harmonic model of linguistic well-formedness [33] and its ramifications and extensions by [34–36].

A fair amount of research has considered the relative harmony of adjacent sounds and constraints governing the occurrence of consonant clusters have been proposed [37–40]. This study is intended to present initial descriptive observations in relation to frequencies of occurrence of root consonants. Simple tables with frequencies of occurrence are used instead of heatmaps or charts since differences in co-occurrences are often in fractions of a percentile, which makes heatmaps or bar-graphs rather confusing. The study invites more in-depth theoretical investigations with reference to Optimality Theory, typological ross-linguistic comparisons, and statistical testing of results using significance tests or confidence intervals.

3. Results and Discussion

Arabic triliteral roots are sequences of three consonants. They are bound morphemes which cannot stand alone with meaning. The conception of roots in Arabic is confusing for many researchers who think that they contain vowels. Arabic native speakers know that Arabic roots cannot be articulated as having meaning, they are often uttered in a fixed pattern k-t-b, meaning "to write", which is identical to the past verb template kataba which means "he wrote".

Arabic has a rich morphology for word derivation and inflection. In adding vowels and certain consonants to words, they become meaningful. For example, the root k-t-b suggests the broad meaning "to write". The consonants k-t-b will be the same, but the pronunciation and meaning will change when adding certain vowels or consonants. Consider the following examples which share the same root k-t-b:

kataba	"to write"
kitaab	"a book"
kaatib	"writer"
maktaba	"a library"
kutub	"books"

This paper provides a detailed analysis for each of these root sequences in (C1C2) position. These sequences will be examined with regard to their place of articulation, manner of articulation, and voicing. To show how the percentages are calculated, let's consider the following sample of Arabic triliteral roots that begin with the alveolar /t/ in (C1) position. This percentage is calculated by dividing each observed co-occurrence by the corresponding total number of the triliteral roots found in *Assehah* dictionary and *Al-Ayn* dictionary.

تأر- تبب – تبر- تبع – تبل – تبن – تجر – تحف – تخخ – تخم – ترب - ترح – ترخ – ترس – ترع – ترف – ترك – تره – تسع – تعب – تعس – تفح – تفف – تفك – تفل – تفه – تقن – تقو – تقي – تكك – تكي – تلد – تلع – تلف – تلل – تلم –تله – تلو – تمر – تمم – تنأ – تهم – توب – توج – توق – توه – تيح – تير – تيس – تيل – تيم – تيه.

As shown in the sample, 52 triliteral roots start with /t/. Five roots have the sequence /t b/ as (C1C2), and the percentage is calculated as: {5 ÷ 52 = 0.0961538} (approximately 10%). So, the percentage is calculated by dividing each ob-

served co-occurrence by the corresponding total number of the triliteral roots found in *Assehah* dictionary and *Al-Ayn* dictionary.

Before detailing the C1C2 sequences, **Table 1** includes the total numbers of roots found with each consonant in the position of (C1) and in the position of (C2). The values stated in the table below represent a total number of 4,738 Arabic triliteral roots beginning with 28 Arabic consonants.

Table 1. C1C2 Sequences in Relation to Place of Articulation.

Consonant as (C1)	Number of Roots	Consonant as (C2)	Number of Roots
Bilabials	653	Bilabials	735
b	243	b	218
m	209	m	223
w	201	w	294
Labio-dental	225	Labio-dental	162
f	225	f	162
Inter-dental	90	Inter-dental	84
θ	47	θ	30
ð	43	ð	54
Alveolar	1691	Alveolar	1326
t	69	t	60
d	182	d	136
s	242	s	103
z	142	z	106
l	156	l	213
n	301	n	160
r	247	r	305
$s^ʕ$	148	$s^ʕ$	83
$d^ʕ$	66	$d^ʕ$	50
$t^ʕ$	125	$t^ʕ$	92
$ð^ʕ$	13	$ð^ʕ$	18
Post-alveolar	420	Post-alveolar	228
ʃ	233	ʃ	108
ʤ	187	ʤ	120
Palatal	29	Palatal	215
j	29	j	215
Velar	207	Velar	97
k	207	k	97
Uvular	606	Uvular	268
q	288	q	131
ɣ	134	ɣ	67
x	184	x	70
pharyngeal	470	pharyngeal	210
ʕ	249	ʕ	110
ħ	221	ħ	100
Glottal	347	Glottal	152
ʔ	192	ʔ	53
h	155	h	99

The left half of the table, values express the numbers of roots which begin with each consonant in (C1) position. The right half of the table is the number of roots with each consonant in (C2) position. Naturally, alveolar consonants standout since they represent the biggest portion of consonants which are [t, d, s, l, n, r, $s^ʕ$, $d^ʕ$, $t^ʕ$, $ð^ʕ$]. A total of 1,691 Arabic triliteral roots begin with alveolar consonant as (C1) and (1326) have their (C2) position occupied by an alveolar consonant. Additionally, the most favorable consonant to occupy (C1) is [n] with 301 roots but when calculating triliteral roots with [n] in (C2) position, only (160) triliteral roots were found. Moreover, [r] is found in a total of 305 triliteral roots occupying the position of (C2). In contrast, only 13 roots are found with [$ð^ʕ$] as (C1).Similarly, 18 roots are found with [$ð^ʕ$] in the position of (C2). It can be noticed that [j] consonant occupies the position of (C1) in only 29

triliteral roots but 215 as (C2). Generally, many consonants can be found in high representations in (C1) and lower in (C2) and the other way round. This indicates that the position of consonants affects their co-occurrence.

3.1. Analysis of (C1C2) in Terms of Place of Articulation

In this section, consonants sequencing in the positions of (C1C2) will be investigated in the view of place of. A number of co-occurrence sequences are selected to represent the whole consonant combination in (C1C2). These selected sequences will represent the majority of the possibilities of the consonantal co-occurrences found in (C1C2) position. The selected samples are:

a. Labial consonants as (C1) and dorsal consonants as (C2).
b. Dorsal consonants as (C1) and labial consonants as (C2).
c. Dorsal consonants as both (C1) and (C2).
d. Coronal consonants as both (C1) and (C2).
e. Coronal consonants as (C1) and labial consonants as (C2).
f. Pharyngeal consonants as (C1) and glottal consonants as (C2).
g. Pharyngeal consonants as both(C1) and (C2).
h. Coronal Continuants as both(C1) and (C2).
i. Coronal Non-Continuants as both (C1) and (C2).

The discussion below will show that more restrictions hold between C1C2 root consonants when the consonants share more than place of articulation. For example, there are more chances for a coronal continuant to be followed by a coronal non-continuant than by a coronal continuant. A brief note follows each table since numbers are self-explanatory.

3.1.1. Labial Consonants (C1) and Dorsal Consonants (C2)

A total of 878 roots begin with labial consonants in (C1) position: 653 bilabials ([b, m, w]) and 225 roots have a labio-dental ([f]). **Table 2** shows that with a following dorsal [j], [k], [x], [ɣ], and [q] in C2 position, the percentage of co-occurrence ranges from 0% to 7%. Approximants [w] and [j] forbidden and [w] equally favors [k] and [q] in C2 position with 7%.

Table 2. Labial Consonants (C1) And Dorsal Consonants (C2).

Place of Articulation			Dorsals (C2)				
			Palatal	Velars	Uvulars		
			j	k	x	ɣ	q
Labials (C1)	Bilabials	b	3%	3%	5%	3%	4%
		m	5%	4%	4%	4%	2%
		w	0%	7%	2%	2%	7%
	Labio-dental	f	5%	2%	3%	2%	5%

3.1.2. Dorsal Consonants (C1) and Labial Consonants (C2)

Table 3 shows the opposite order of consonants discussed in **Table 2**. A total of 842 roots begin with dorsals with higher chances for a labial in C2 position compared to the opposite direction. No full restriction even between approximants, and the favored labial in C2 position is [w].

3.1.3. Dorsal Consonants in the Position of (C1) and (C2)

Table 4 shows that Dorsals in both C1 and C2 positions exhibit high degrees of restriction. This is consistent with the *Obligatory Contour Principle* (OCP) which prohibits the adjacency of identical consonants [26]. The uvular [ɣ] in (C1) only occurs with [q] at a rather low frequency, and [q] is only followed by [j]. The co-occurrence of homorganic consonants in adjacent positions can be primarily suggested to be more constrained (but not completely restricted).

3.1.4. Coronal Consonants in the Position of (C1) and (C2)

There are 2,201 Arabic triliteral roots that begin with coronal consonants: 1,691 begin with alveolars, 420 with post-alveolars, and 90 with inter-dentals. The majority of

coronals favor pairing with [l], [r], and [n] as (C2). The highest percentages as observed are for [r] when it is in (C2) position. This shows that [r] is a preferable consonant to occupy the position of (C2) in Arabic triliteral roots when (C1) is a coronal. In contrast, Arabic triliteral roots prohibit the sequences of [lr], [rl], [ln], and [nl] from forming (C1C2) sequences. They are constrained by the place of articulation feature.

Table 3. Dorsal Consonants (C1) and Labial Consonants (C2).

Place of Articulation			**Labials (C2)**			
			Labio-Dental		**Bilabial**	
			f	**b**	**m**	**w**
Dorsals (C1)	f	b	m	w		
	Palatal	j	7%	7%	10%	7%
	Velar	k	6%	7%	7%	7%
	Uvular	x	5%	7%	5%	7%
		ɣ	4%	6%	10%	7%
		q	4%	5%	5%	16%

Table 4. Dorsal Consonants (C1) and Dorsal Consonants (C2).

Place of Articulation			**Dorsals (C2)**				
			Palatal	**Velar**	**Uvular**		
			j	**k**	**x**	**ɣ**	**q**
Dorsals (C1)	Palatal	j	0%	0%	7%	0%	10%
	Velar	k	3%	0%	0.5%	2%	0%
	Uvular	x	4%	0%	0%	0%	0.5%
		ɣ	0%	0%	0%	0%	0.7%
		q	7%	0%	0%	0%	0%

Table 5 shows two types of constraints. The first concerns the general place of articulation restriction, and the second concerns the co-occurrence restriction of identical consonants. The alveolar [s] has a co-occurrence restriction with [ð], [z] [sˤ], [dˤ], [ðˤ], and [ʃ]. Even though the post-alveolar [ʤ] as (C1) patterns with most coronals in variable percentages, it does not pair with [t], [dˤ], [tˤ], and [ðˤ]. Additionally, the alveolar [ðˤ] as (C1) favors only [l], [n], and [r] to be in an adjacent position as (C2). Moreover, the alveolar [z] as (C1) disallows the majority of coronals to occur adjacently in (C1C2) position. It only allows [ʤ], [l], [n], and [r]. All coronal plosives in (C1) do not allow coronal plosives to occupy the adjacent position of (C2), except [dˤ] and [d] as (C1C2). This is mainly because they share the same place and manner of articulation. Similarly, it is almost impossible to have a fricative coronal as (C1) with another fricative coronal as (C2). This also supports the idea that the more phonetic features are shared by a certain class of consonants, the less they co-occur in adjacent positions.

Interestingly, the voiced inter-dental [ð] as (C1) only favors [l], [r], and [n] to occur in (C2) position. It bans all other coronals from occupying (C2) position. The voiceless inter-dental [θ] as (C1) prohibits most coronal consonants to be in the position of (C2), except for [d], [ʤ], [l], [r], and [n]. One more example on co-occurrence restrictions is the case of the alveolar [t] as (C1). This consonant doesn't accept forming a sequence with [θ], [ð], [z], [d], [dˤ] [tˤ], [ðˤ], and [ʃ].

Table 5. Coronal Consonants in the Position of (C1) and (C2).

Place of Articulation			Coronals (C2)														
			Inter-Dentals		Alveolars										ost-Alveolars		
			θ	ð	t	d	s	z	l	n	r	sˤ	dˤ	tˤ	ðˤ	ʃ	ʤ
Coronals (C1)	Post-alveolars	ʤ	3%	5%	0%	6%	4%	5%	10%	6%	12%	1%	0%	0%	0%	3%	0%
		ʃ	0%	2%	2%	4%	0.4%	0.4%	3%	6%	10%	0.8%	0%	3%	0.8%	0%	3%
	Alveolars	ðˤ	0%	0%	0%	0%	0%	0%	30%	15%	20%	0%	0%	0%	0%	0%	0%
		tˤ	0%	0%	0%	0%	0.8%	2%	9%	7%	20%	0%	0%	0%	0%	0.8%	0%
		dˤ	0%	0%	0%	2%	0%	0%	3%	5%	15%	0%	0%	0%	0%	0%	5%
		sˤ	0%	0%	0.7%	6%	0%	0%	10%	9%	7%	0%	0%	1%	0%	0%	0%
		r	1%	20%	4%	4%	5%	4%	0%	3%	0%	2%	3%	2%	0%	4%	6%
		n	0.3%	0.6%	2%	3%	5%	4%	0%	0%	2%	3%	3%	3%	1%	5%	4%
		l	2%	5%	0.6%	2%	1%	3%	0%	0%	0%	1%	0.6%	4%	0.6%	0.6%	4%
		z	0%	0%	0%	0%	0%	0%	6%	10%	8%	0%	0%	0%	0%	0%	3%
		s	0%	0.8%	1%	4%	0%	0%	9%	8%	10%	0%	0%	2%	0%	0%	5%
		d	0.5%	0%	0%	0%	4%	0%	8%	7%	12%	0%	0%	0%	0%	3%	3%
		t	0%	0%	0%	0%	2%	0%	13%	2%	16%	0%	0%	0%	0%	0%	2%
	Inter-dentals	ð	0%	0%	0%	0%	0%	0%	10%	2%	20%	0%	0%	0%	0%	0%	0%
		θ	0%	0%	0%	2%	0%	0%	10%	6%	15%	0%	0%	0%	0%	0%	2%

The second constraint concerns identical consonants; they cannot form the combination of (C1C2) sequence. This coincides with the Obligatory Contour Principle (OCP) which holds against the adjacency of identical pairs of sounds[25]. Moreover, [l] as (C1) and [r] as (C2) have a co-occurrence constraint. The same thing is applied when the positions of [l] and [r] are reversed. The ratio for [r] as (C1) or (C2) to be adjacent with [l] as (C1) or (C2) is (0%) because they share the same point of articulation and this blocks them from being in adjacent positions.

3.1.5. Coronal Consonants (C1) and Labial Consonants (C2)

Table 6 shows that all labial consonants as (C2) are allowed to form sequences of (C1C2) with a coronal in (C1) except for the coronal alveolar [ðˤ] which cannot be followed by the labial [w]. It is clear that when the difference in place of articulation is bigger, the possibilities become higher.

Table 6. Coronal Consonants (C1) and Labial Consonants (C2).

Place of Articulation			Labials (C2)			
			Bilabials		Labio-Dental	
			b	m	w	f
Coronals (C1)	Post-alveolars	ʤ	5%	7%	10%	4%
		ʃ	6%	5%	7%	5%
	Alveolars	ðˤ	8%	8%	0%	8%
		tˤ	9%	9%	9%	7%
		dˤ	10%	10%	8%	6%
		sˤ	6%	6%	10%	7%
		r	7%	6%	7%	7%
		n	6%	4%	10%	6%
		l	9%	6%	10%	5%
		z	6%	7%	8%	4%
		s	7%	8%	9%	7%
		d	5%	8%	11%	5%
		t	10%	4%	8%	10%
	Inter-dentals	ð	10%	7%	11%	2%
		θ	12%	9%	6%	6%

3.1.6. Pharyngeal Consonants (C1) and Glottal Consonants (C2)

A total of 470 roots begin with a pharyngeal consonant. (249) begin with the pharyngeal [ʕ], and 221 with [ħ]. **Table 7** shows that, generally speaking, the co-occurrence of pharyngeals in (C1) and glottals in (C2) is restricted.

Table 7. Pharyngeals As (C1) and Glottals As (C2).

Place of Articulation		Glottals (C2)	
		ʔ	h
Pharyngeal (C1)	ʕ	0%	2%
	ħ	0%	0%

3.1.7. Pharyngeal Consonants in the Position of (C1) and (C2)

Table 8 shows that Pharyngeal Consonants in (C1) and (C2) Are Prohibited.

Table 8. Pharyngeal Consonants (C1) and Pharyngeal Consonants (C2).

Place of Articulation		Pharyngeal (C2)	
		ʕ	ħ
Pharyngeal (C1)	ʕ	0%	0%
	ħ	0%	0%

3.1.8. Coronal Continuants as (C1) and (C2)

A total of 848 triliteral roots begin with a coronal continuant. **Table 9** shows that the occurrence of [l] and [r] is higher in (C2) position than in (C1). They allow any coronal continuant to occur adjacently. Mostly, the emphatics [ðˤ] and [sˤ] have 0% representations. This means that they do not favor pairing with other coronal continuants. They only prefer to occur in (C2) position after [l] and [r]. There are many instances of (0%) frequencies indicating that when consonants share more than one feature, the possibility of co-occurring in adjacent positions becomes less.

Table 9. Coronal Continuants as (C1) and (C2).

Place and Manner of Articulation		Coronal Continuants (C2)									
		ʤ	ʃ	ðˤ	sˤ	r	l	z	s	ð	θ
Coronal Continuants (C1)	ʤ	0%	3%	0%	1%	12%	10%	5%	4%	5%	3%
	ʃ	3%	0%	0.8%	0.8%	10%	3%	0.4%	0.4	2%	0%
	ðˤ	0%	0%	0%	0%	20%	30%	0%	0%	0%	0%
	sˤ	0%	0%	0%	0%	7%	10%	0%	0%	0%	0%
	r	6%	4%	0%	2%	0%	0%	4%	5%	20%	1%
	l	4%	0.6%	0.6%	1%	0%	0%	3%	1%	5%	2%
	z	3%	0%	0%	0%	8%	6%	0%	0%	0%	0%
	s	5%	0%	0%	0%	10%	9%	0%	0%	0.8%	0%
	ð	0%	0%	0%	0%	20%	10%	0%	0%	0%	0%
	θ	2%	0%	0%	0%	15%	10%	0%	0%	0%	0%

3.1.9. Coronal Non-Continuants as (C1) and (C2)

A total of 743 triliteral roots have a coronal non-continuant consonant in (C1) position. From the values stated in **Table 10**, one can say that coronal non- continuant consonants are almost completely restricted to occur with other non- continuants coronal in (C1C2) clusters. [dˤ] is the only consonant that can pair with [d] but with a low value. Once more, the more features shared, the less possible is the co-occurrence.

Table 10. Coronal Non-Continuants as (C1) and (C2).

Place and Manner of Articulation		Coronal Non-Continuants (C2)				
		t	d	n	dˤ	tˤ
Coronal Non-Continuants (C1)	t	0%	0%	2%	0%	0%
	d	0%	0%	7%	0%	0%
	n	2%	3%	0%	3%	3%
	dˤ	0%	2%	5%	0%	0%
	tˤ	0%	0%	7%	0%	0%

3.2. Analyzing (C1C2) in Terms of Manner of Articulation

To investigate the existence of co-occurrence restrictions based on the manner of articulation of consonants in Arabic triliteral roots, the researcher selected a number of sequences to represent the whole consonants in the position of (C1C2). These selected sequences will cover the majority of the possibilities of the consonant co-occurrences found in (C1C2) position. The selected samples are:

1. Plosives as (C1) and Nasals as (C2).
2. Nasals as (C1) and Plosives as (C2).
3. Plosives as (C1) and as (C2).

4. Fricatives as (C1) and Fricatives as (C2).
5. Fricatives as (C1) and Approximants as (C2).
6. Approximants as (C1) and Fricatives as (C2).
7. Approximants as (C1) and as (C2).
8. Sonorants as (C1) and (C2).

Again, the discussion shows that when consonants share more than one feature, the chances for their appearance in a sequence is reduced.

3.2.1. Plosives as (C1) and Nasals as (C2)

A total of 1,371 roots begin with a plosive. **Table 11** shows that even though the bilabial plosive [b] and the bilabial nasal [m] belong to different categories with regard to their manner of articulation, their co-occurrence in (C1C2) position is constrained. This is definitely because they share the same place of articulation. Except this case, all plosives and nasals are not subject to co-occurrence constraints. On the other hand, the [dˤ] has a strong tendency to pattern with [m] in (C1C2) sequence.

Table 11. Plosives as (C1) and Nasals as (C2).

Manner of Articulation		Nasals (C2)	
		m	**n**
Plosives (C1)	b	0%	3%
	t	4%	4%
	k	7%	7%
	ʔ	4%	7%
	tˤ	9%	7%
	d	8%	7%
	q	5%	9%
	dˤ	10%	5%

3.2.2. Nasals as (C1) and Plosives as (C2)

A total of 518 Arabic triliteral roots have a nasal consonant as (C1). Generally, **Table 12** shows that the percentages for nasal consonants in the position (C1) and plosives in (C2) are lower than plosives in (C1) and nasals in (C2).

Table 12. Nasals as (C1) and Plosives as (C2).

Manner of Articulation		Plosives (C2)							
		b	**t**	**k**	**ʔ**	**tˤ**	**d**	**q**	**dˤ**
Nasals (C1)	m	0%	3%	4%	1%	5%	3%	2%	2%
	n	6%	2%	5%	0.6%	3%	3%	6%	3%

3.2.3. Plosives as (C1) and (C2)

In **Table 13**, most of the (0%) frequencies confirm that identical consonants are not allowed to co-occur. On the other hand, the other (0%) values are for co-occurrence restrictions. For example, the plosive [t] as (C1) is constrained to co-occur with the plosives [dˤ], [d], and [tˤ] as (C2). This is caused mainly by sharing the same place of articulation.

It is also observed that coronal plosives as (C1) favor almost any other plosive that does not have the same place of articulation as (C2). This means that it is possible for plosives to co-occur with other plosives when they have dissimilar place of articulation which indicates that consonants are more restricted when they share more than one feature.

Table 13. Plosives as (C1) and Plosives as (C2).

Manner of Articulation		Plosives (C2)							
		b	**t**	**k**	**ʔ**	**tˤ**	**d**	**q**	**dˤ**
Plosives (C1)	b	0%	2%	3%	2%	6%	3%	4%	0.8%
	t	7%	0%	4%	3%	0%	0%	4%	0%
	k	7%	4%	0%	2%	0%	3%	0%	0%
	ʔ	9%	2%	4%	0%	0.2%	3%	3%	0%
	tˤ	9%	0%	0%	2%	0%	0%	4%	0%
	d	5%	0%	2%	0.5%	0%	0%	3%	0%
	q	5%	2%	0%	0.1%	4%	3%	0%	2%
	dˤ	10%	0%	0%	3%	0%	2%	0%	0%

3.2.4. Fricatives as (C1) and Fricatives as (C2)

There are 2,228 triliteral roots found with fricatives in the first position of the root (C1). **Table 14** shows that identical consonants are not allowed to co-occur in an adjacent (C1C2) position. It is observed that 73 instances out of 169 possible fricative-fricative combinations, the co-occurrence frequency is (0%). This indicates that with more shared phonetic features, restrictions hold tighter. For instance, the sound [s] as (C1) cannot be followed by [s, θ, ʃ, ðˤ, sˤ, z] because they are homo-organic (alveolar and palato-alveolar).

Table 14. Fricatives as (C1) and Fricatives as (C2).

Manner of Articulation		Fricatives (C2)												
		s	**θ**	**ð**	**ʃ**	**ðˤ**	**sˤ**	**ħ**	**z**	**ʕ**	**ɣ**	**f**	**h**	**x**
Fricatives (c1)	s	0%	0%	1%	0%	0%	0%	5%	0%	4%	0%	7%	3%	4%
	θ	0%	0%	0%	0%	0%	0%	0%	0%	4%	6%	6%	0%	2%
	ð	0%	0%	0%	0%	0%	0%	4%	0%	5%	3%	5%	6%	3%
	ʃ	0%	0%	2%	0%	1%	1 %	4%	0%	5%	4%	5%	4%	2%
	ðˤ	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	8%	8%	0%
	sˤ	0%	0%	0%	0%	0%	0%	6%	0%	4%	2%	7%	5%	1%
	ħ	4%	2%	3%	4%	2%	5%	0%	3%	0%	0%	4%	0%	0%
	z	0%	0%	0%	0%	0%	0%	5%	0%	10%	10%	4%	4%	3%
	ʕ	5%	2%	2%	4%	1%	4%	0%	4%	0%	0%	3%	2%	0%
	ɣ	3%	1%	1%	3%	0%	2%	0%	3%	0%	0%	4%	0%	0%
	f	6%	0%	1%	3%	1%	4%	3%	1%	2%	2%	0%	3%	3%
	h	1%	0%	3%	1%	0%	10%	0%	6%	0%	0%	3%	0%	0%
	x	3%	1%	3%	5%	0%	4%	0%	5%	0%	0%	5%	0%	0%

3.2.5. Fricatives as (C1) and Approximants as (C2)

From the analysis stated in the **Table 15**, it can be noted that there are high percentages for the co-occurrence of fricatives and approximants in (C1C2) position respectively. Only [ðˤ] as (C1) disfavors [j] and [w] to be in an adjacent position as (C2). So, the consonantal combinations [ðˤ j] and [ðˤ w] are not allowed in Arabic triliteral roots. It is also observed that [l] and [r] are desirable to be in (C2) position after fricatives.

Table 15. Fricatives as (C1) and Approximants As (C2) in Arabic Triliteral Roots.

Manner of Articulation		Approximants (C2)			
		w	**j**	**l**	**r**
Fricatives (C1)	s	9%	5%	9%	10%
	θ	6%	2%	10%	15%
	ð	11%	5%	10%	20%
	ʃ	7%	5%	3%	10%
	ðˤ	0%	0%	30%	20%
	sˤ	10%	8%	10%	7%
	ħ	10%	6%	6%	10%
	z	8%	8%	6%	8%
	ʕ	6%	5%	6%	10%
	ɣ	7%	10%	10%	13%
	f	6%	5%	10%	17%
	h	9%	10%	8%	10%
	x	7%	4%	5%	15%

3.2.6. Approximants as (C1) and Fricatives as (C2)

Table 16 shows that the most preferable sequence of approximant-fricative consonants is [j] as (C1) and [s] as (C2). When the values are generally compared to those found when examining the co-occurrence of approximants as (C2) adjacently to fricatives as (C1) in **Table 15**, we can easily notice that possibilities of approximants-fricatives co-occurrence in (C1C2) are lower than fricatives-approximants co-occurrences. Additionally, the fricative consonants [ð], [ʃ], [ðˤ], [sˤ], [ɣ], and [h] are not allowed to occupy the position of (C2) forming sequences with the approximant consonant (j) as (C1) while the same fricative consonants [ð], [ʃ], [ðˤ], [sˤ], [ɣ], and [h] as (C1) in **Table 15** allow the approximant [j] to occupy the adjacent position (C2). Similarly, the adjacency of the fricative [ðˤ] as (C2) to the approximant [r] as (C1) is completely blocked while a sequence of [ðˤr] is found possible expressed by the value (20%) in **Table 15** when examining [ðˤ] as C1 and [r] as (C2). Such differences support the fact that the consonant [r] is preferable as (C2) more than as (C1). On the other hand, this highlights the idea that the influence of the restrictions is more on approximants-fricatives co-occurrences as (C1C2) than on fricatives-approximants as (C1C2).

Table 16. Approximants As (C1) and Fricatives as (C2) in Arabic Triliteral Roots.

Manner of Articulation		Fricatives (C2)													
		s	θ	ð	ʃ	ʤ	ðˤ	sˤ	ħ	z	ʕ	ɣ	f	h	x
Approximants (C1)	w	6%	3%	0.6%	7%	6%	1%	4%	4%	4%	7%	2%	3%	5%	2%
	j	10%	3%	0%	0%	0%	0%	0%	3%	3%	3%	0%	7%	0%	7%
	l	1%	2%	5%	0.6%	4%	0.6%	1%	7%	3%	4%	4%	5%	8%	3%
	r	5%	1%	0.2%	4%	6%	0%	2%	3%	4%	5%	3%	7%	5%	2%

3.2.7. Approximants as (C1) and Approximants as (C2)

The co-occurrence of identical approximant consonants is totally banned as found in **Table 17**. On the other hand, the approximant [w] and [j] can occur with all approximant except when C1 and C2 are identical. The approximant [w] in C2 is more preferable than [j]. In addition, the consonants [l] and [r] are not allowed to occupy adjacent positions in (C2) when [l] and [r] are in (C1). In contrast, other approximants, namely [w] and [j] are found in high percentages occupying adjacent positions to [l] and [r].

Table 17. Approximants As (C1) And (C2) in Arabic Triliteral Roots.

Manner of Articulation		Approximants (C2)			
		w	j	l	r
Approximants (C1)	w	0%	0.1%	7%	8%
	j	7%	0%	0%	10%
	l	10%	5%	0%	0%
	r	7%	5%	0%	0%

3.2.8. Sonorant Consonants as (C1) and (C2)

A total of 1,143 Arabic triliteral roots begin with a sonorant consonant. **Table 18** shows that the co-occurrence of sonorant consonants has a different behavior compared to other consonants sharing the same feature. Consonants which belong to the same natural class tend to exhibit more co-occurrence restrictions than when different classes of sounds are analyzed. The bilabial nasal [m] and the alveolar nasal [n] can occur adjacent to all sonorants except when (C1) is occupied by the coronal approximant [l]. Similarly, when [n] is in (C1), it can be followed by all other sonorants except [l]. On the other hand, sonorants co-occurrence is not as high as when they were observed in other tables. This means that even though sonorant consonants are preferable and they occur in relatively high percentages, but their co-occurrence in adjacent positions is more restricted since they share more than one feature.

Table 18. Sonorants as (C1) and (C2) in Arabic Triliteral Roots.

Manner of Articulation		Sonorants (C2)					
		w	**j**	**l**	**r**	**m**	**n**
Sonorants (C1)	w	0%	0%	7%	8%	3%	1%
	j	7%	0%	0%	10%	10%	10%
	l	10%	5%	0%	0%	6%	0%
	r	7%	5%	0%	0%	6%	3%
	m	4%	5%	7%	10%	0%	4%
	n	10%	4%	0%	2%	4%	0%

3.3. Analyzing (C1C2) in Terms of Voicing Feature

The voicing feature will be surveyed to find out what blocks consonant sequencing in Arabic triliteral roots. It has been found that 2,278 out of 4,738 Arabic triliteral roots begin with a voiceless consonant. In this section, the researcher will investigate whether voicing has a strong effect on consonants to co-occur in (C1C2) position or not.

The discussion shows that voicing in itself is irrelevant in determining C1C2 sequences. Place and Manner are more influential.

3.3.1. Voiced Consonants as (C1) and Voiced Consonants as (C2)

Table 19 below shows that the duplicates of the same consonants are not allowed in (C1C2) position. Moreover, in most cases, homorganic consonants are not permitted to form successive sequences. The data also indicates that voicing, place, and manner of articulation co-occurrence restrictions have more influence when at least two of them are shared in a sequence. For example, the voiced [b] and the voiced [r] can form the sequence of (C1C2) although they are both voiced, but [b] is a bilabial plosive and [r] is a coronal fricative. Moreover, the alveolar [d] patterns with the alveolar [l] since [d] are plosive and [l] is an approximant. One more example is the fricative [z] which pairs with [ɣ] in an adjacent position. It is obvious that the influence of the voicing feature is not enough to block the adjacency of consonants.

3.3.2. Voiced Consonants as (C1) and Voiceless Consonants as (C2)

Table 20 shows that there is variation in the co-occurrence pattern of Arabic triliteral roots about the voicing feature. There are a lot of (0%) representations in the table below. For example, the consonants [ðˤ], [ʕ], and [ɣ] don't allow [ʔ], [x], and [ħ] to be adjacent in (C2) position. Another example is that [ʤ], [d], [ð], [z], [dˤ], [ðˤ], and [ʕ] do not pattern with [t]. Furthermore, [dˤ], [ðˤ], and [ʕ] do not form a sequence with [θ].In addition, [z], [dˤ], and [ðˤ] cannot co-occur with [s], [ʃ], [sˤ], and [tˤ]. Also, the voiced labial [b] and [m] do not favor the voiceless labio-dental [f] to be in (C2) position. The (0%) values are not due to the voicing feature only, but also to other features. So, there are co-occurrence restrictions when consonants share voicing, place of articulation and manner features.

Table 19. Voiced Consonants as C1 and Voiced Consonants as C2 in Arabic Triliteral Roots.

Voicing		Voiced (C2)														
		b	**ʤ**	**d**	**ð**	**r**	**z**	**dˤ**	**ðˤ**	**ʕ**	**ɣ**	**l**	**m**	**n**	**w**	**j**
Voiced (C1)	b	0%	3%	3%	2%	20%	2%	1%	1%	4%	3%	10%	0%	3%	7%	3%
	ʤ	5%	0%	6%	5%	12%	5%	0%	0%	3%	0%	10%	7%	6%	10%	3%
	d	5%	3%	0%	0%	0%	0%	0%	0%	5%	3%	8%	8%	7%	11%	4%
	ð	10%	0%	0%	0%	20%	0%	0%	0%	10%	0%	10%	7%	2%	11%	5%
	r	7%	6%	4%	0%	0%	4%	3%	0%	5%	3%	0%	6%	3%	7%	5%
	z	6%	3%	0%	0%	8%	0%	0%	0%	10%	10%	6%	7%	10%	8%	8%
	dˤ	10%	5%	2%	0%	15%	0%	0%	0%	3%	6%	3%	10%	5%	8%	8%
	ðˤ	8%	0%	0%	0%	20%	0%	0%	0%	8%	0%	30%	8%	15%	0%	0%
	ʕ	6%	4%	2%	2%	10%	4%	2%	1%	0%	0%	6%	4%	10%	6%	0%
	ɣ	6%	0%	5%	1%	13%	3%	4%	0%	0%	0%	10%	10%	5%	7%	0%

Table 19. *Cont.*

Voicing		Voiced (C2)														
		b	**ʤ**	**d**	**ð**	**r**	**z**	**dˤ**	**ðˤ**	**ʕ**	**ɣ**	**l**	**m**	**n**	**w**	**j**
Voiced (C1)	l	9%	4%	2%	5%	0%	3%	1%	1%	4%	4%	0%	6%	0%	10%	5%
	m	0%	3%	3%	2%	10%	4%	2%	0%	6%	4%	7%	0%	4%	4%	5%
	n	6%	4%	3%	1%	2%	4%	3%	1%	4%	3%	0%	4%	0%	10%	4%
	w	3%	6%	4%	1%	8%	4%	3%	1%	7%	2%	7%	3%	1%	0%	0%
	j	7%	0%	0%	0%	10%	3%	0%	0%	3%	0%	0%	10%	10%	7%	0%

Table 20. Voiced Consonants As (C1) and Voiceless Consonants As (C2).

Voicing		Voiceless (C2)												
		ʔ	**t**	**θ**	**ħ**	**x**	**s**	**ʃ**	**sˤ**	**tˤ**	**f**	**q**	**k**	**h**
Voiced (C1)	b	2%	2%	1%	4%	5%	5%	2%	2%	6%	0%	4%	3%	6%
	ʤ	2%	0%	3%	4%	1%	4%	3%	1%	0%	4%	0%	1%	4%
	d	1%	0%	1%	4%	3%	4%	3%	0%	0%	5%	3%	2%	6%
	ð	2%	0%	0%	2%	2%	0%	0%	0%	0%	2%	2%	7%	7%
	r	3%	4%	1%	3%	2%	5%	4%	2%	2%	7%	5%	4%	5%
	z	4%	0%	0%	5%	3%	0%	0%	0%	0%	4%	4%	4%	4%
	dˤ	3%	0%	0%	8%	8%	0%	0%	0%	0%	6%	0%	0%	6%
	ðˤ	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	8%
	ʕ	0%	4%	2%	0%	0%	5%	4%	4%	4%	3%	5%	4%	2%
	ɣ	0%	1%	1%	0%	0%	3%	3%	2%	5%	4%	1%	0%	0%
	l	2%	1%	2%	7%	3%	1%	1%	1%	4%	5%	7%	4%	8%
	m	1%	3%	1%	5%	4%	6%	4%	2%	5%	0%	2%	4%	5%
	n	1%	2%	0%	3%	3%	5%	5%	3%	3%	6%	6%	5%	4%
	w	2%	2%	3%	4%	2%	6%	7%	4%	6%	3%	7%	7%	5%
	j	3%	3%	3%	3%	7%	10%	0%	0%	0%	7%	10%	0%	0%

3.3.3. Voiceless Consonants as (C1) and Voiceless Consonants as (C2)

Table 21 shows that the possibility of consonants which share more than one feature (voicing, manner of articulation, and place of articulation) lessens to become (0%). The fricative [s], for example, does not permit some fricatives to be in adjacent (C2) position. On the other hand, it permits other fricatives to be in (C2) position. This means that manner of articulation feature alone is not enough to block sequences in (C1C2) position. Moreover, from the statistics in the table below, [-voicing] is not the only factor that restricts consonants from co-occurring.

Table 21. Sequences of Voiceless Consonants As (C1) and Voiceless Consonants As (C2).

Voicing		Voiceless (C2)												
		ʔ	**t**	**θ**	**ħ**	**x**	**s**	**ʃ**	**sˤ**	**tˤ**	**f**	**q**	**k**	**h**
Voiceless (C1)	ʔ	0%	2%	3%	1%	2%	9%	2%	2%	0%	5%	3%	4%	1%
	t	3%	0%	0%	1%	4%	1%	0%	0%	0%	7%	4%	4%	3%
	θ	4%	0%	0%	0%	2%	0%	0%	0%	0%	6%	6%	4%	0%
	ħ	0%	3%	2%	0%	0%	4%	4%	5%	2%	4%	3%	2%	0%
	x	0%	2%	1%	0%	0%	3%	5%	4%	5%	5%	1%	0%	0%
	s	1%	1%	0%	5%	4%	0%	0%	0%	2%	7%	5%	3%	3%
	ʃ	2%	2%	0%	4%	2%	0 %	0%	1%	3%	5%	4%	3%	4%
	sˤ	1%	1%	0%	6%	1%	0%	0%	0%	1%	7%	3%	1%	5%
	tˤ	2%	0%	0%	4%	2%	1%	1%	8%	0%	7%	4%	0%	4%
	f	3%	6%	0%	3%	3%	6%	3%	4%	3%	0%	5%	2%	3%
	q	0%	2%	1%	2%	0%	3%	5%	5%	4%	4%	0%	0%	2%
	k	2%	4%	2%	2%	1%	7%	5%	0%	0%	6%	0%	0%	3%
	h	1%	4%	0%	0%	0%	1%	1%	10%	1%	3%	0%	2%	0%

4. Conclusions

The present study aimed to find which consonants occur in C1 and C2 positions in Arabic triliteral roots, and how many roots are found with each consonant (Research Question 1). Results showed that all 28 Arabic consonants may occur in C1 and C2 position within the root in varying frequency (**Table 1**). 301 roots have an alveolar nasal [n] in C1 position, whereas only 13 roots begin with the emphatic interdental fricative [ðˤ]. Moreover, [r] is the most frequent consonant in C2 position with 305 roots compared to only 18 roots with [ðˤ] as C2.

The study also investigated phonetic features that restrict the co-occurrence of consonants in C1C2 position (Research Question 2). Results showed that place of articulation was the primary force behind restrictions. Manner of articulation and voicing relatively influenced these restrictions and were active only in combination with place (Research Question 3).

The study confirms the results in Coetzee and Pater where place of articulation is active in restricting C1C2 adjacency in roots[27]. The study, however, departs in confirming that place of articulation restricts the co-occurrence of consonants in the sequences (C1C2) gradiently. Some coronal consonants are found to form root sequences. In contrast, other place of articulation features block adjacency categorically. Instances of this restriction can be found in **Tables 4** and **7** when glottal and pharyngeal consonants are constrained by the place feature. It was also found that consonants sharing more than one feature are more restricted than those sharing only one feature. This can be observed in **Tables 9** and **10** when the value (0%) represents the co-occurrence of the majority of coronals sharing same manner.

Sonorant consonants [l, m, n, r, w, and j] are generally preferable to occupy adjacent positions regardless of the preceding consonant. The most preferable ones are [l], [n], and [r] since they have the highest percentages among all. However, they can occupy adjacent positions to all consonants except when (C1) is [l], [n], or [r], the co-occurrence then is restricted.

In light of the previous discussion and conclusions, the following recommendations may be suggested for students, future researchers, and those who are interested in studying Arabic roots. First, it is recommended that Arabic biliteral, quadriliteral, and pentaliteral roots be investigated in terms of restrictions on consonants co-occurrence. Second, examine Arabic consonantal sequences at the morphological level to find out constraints that ban consonants adjacency. Finally, the researchers recommend that a comparative study of consonants co-occurrences in Modern Standard Arabic (MSA) and other dialects.

Author Contributions

Conceptualization, K.A.-A.; methodology, K.A.-A. and Y.A.-O.; analysis and interpretation, K. A.-A. and Y.A.-O.; resources, Y.A.-O.; writing—original draft preparation, K.A.-A. and Y.A.-O. writing—review and editing, K.A.-A. and Y.A.-O.; supervision, K.A.-A. Both authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data used in the study is available in online dictionaries

1. Assihah

https://www.noor-book.com/%D9%83%D8%AA%D8%A7%D8%A8-%D8%A7%D9%84%D8%B5%D8%AD%D8%A7%D8%AD-pdf

2. Al-Ayn

https://www.noor-book.com/%D9%83%D8%AA%D8%A7%D8%A8-%D8%A7%D9%84%D8%B9%D9%8A%D9%86-pdf

Conflicts of Interest

The authors declare no conflict of interest.

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