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Velar-Palatal Alternations in Word Formation in Vedic Sanskrit

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List of Symbols and Abbreviations

Grammatical/Morphological Terms/Symbols

ADJ	adjective
PIE	Proto-Indo-European
CAUS	causative
DES	desiderative
INTENS	intensive
PERF	perfect
PL	plural
SG	singular
DU	dual
M	masculine
F	feminine
N	neuter
NOM	nominative
ACC	accusative
GEN	genitive
ABL	ablative
INSTR	instrumental
LOC	locative
VOC	vocative
REDUP	reduplicated stem
ZG	zero grade stem
FG	full grade stem
LG	lengthened grade stem
V	vowel
C	consonant
O	obstruent
R	sonorant
*	reconstructed form; constraint violation; (possibly) artificial/secondary root
´	accented

-	morpheme boundary; part of a compound
>	diachronic development
→	synchronic development
?	uncertain root/suffix
[]	phonological feature
UR	underlying representation
SR	surface representation

Languages

Av.	Avestan
OAv.	Old Avestan
YAv.	Young Avestan
Goth.	Gothic
Gr.	Greek
Lat.	Latin
OP.	Old Persian
NP.	New Persian
PIE	Proto-Indo-European
PGmc	Proto-Germanic
PIIr.	Proto-Indo-Iranian
Ved.	Vedic

1. Introduction

In the traditional presentation of Sanskrit roots, for those ending in consonantal segments, there are more roots ending in a palatal segment (including *c*, *ch*, *j*, *jh*, *ś*) than a velar (including *k*, *kh*, *g*, *gh*).[1] But etymologically, some of these palatal segments can be derived from PIE velars, labiovelars, and palatovelars (including **k*, **g*, *g^h, **ḱ*, **ǵ*, *$ǵ^h$, *k^w, *g^w, *g^{wh})—their exact Indo-European source, may, at first glance, be ambiguous.[2]. In the following discussion, all rules are summarized based on Kobayashi 2017, Cantera 2017, Macdonell 1910: §297–303 and Whitney 1896: §377–410, with further examples taken from *EWA*, *LIV*[2], *NIL* and Monier-Williams 1899.

Diachronically, Sanskrit *k* can reflect either PIE **k* or *k^w in a non-palatalizing context, e.g., *kravíṣ-* 'raw, bloody meat' < **kreu̯*h_2*-(a)s-*, *ká-* 'who, which' < *k^w*o-*; likewise, Sanskrit *g* can come from either PIE **g* or *g^w, e.g., *bhága-* 'allocator; allocation' < *b^h*ág-o-*, *gáv-* 'cow, ox' < *g^w*óu̯-*. Etymologically, this means one has always to be aware of the PIE phonemes from which they come, which is determined by comparison to *centum* languages.

Sanskrit *kh* comes from PIE **k*/*k^w in non-palatalizing contexts plus *h_2, e.g. *khidáti* 'tears, presses' < **k(*^{w}*)*h_2*d-é-*; Sanskrit *gh* comes from PIE *g^h or *g^{hw} in non-palatalizing contexts, e.g., *gharmá-* 'embers, heat, warmth' < *g^{wh}*or-mó-*. These two phonemes never appear as the final segment of a root.

Sanskrit *c* comes from the PIIr. secondary palatal **č*, which derives from PIE **k*/*k^w when followed by a front vocoid (including PIE **e*, **ē*, **i* or the glide **i̯*), e.g., *múcyate* 'comes free, is liberated' < **muk-i̯é-*, *cakrá-* 'wheel' < PIIr. **čakra-* < PIE *k^w*e*k^w*lo-*; Sanskrit *j* presents a somewhat more complicated situation: it either comes from the PIIr. primary palatal **ȷ́* (Av. *z*) < PIE **ǵ*, e.g. (-)*ā́j-* 'rushing to' < *(-)h_2*aǵ-*, or from the PIIr. secondary palatal **ǰ* (Av. *ǰ*) < PIE **g*/*g^w preceding a front vocoid, e.g. *jīrá-* 'quick, lively, actuating' < *g^w*i*h_3*-ró-*. Similar to Sanskrit *k* and *g*, one has to decide which PIE phonemes Sanskrit *c* and *j* come from.

Sanskrit *ch* comes primarily from PIIr. **sć* < PIE **sḱ* (which is, though, disputed, and sometimes reconstructed as **sk*; see 4.10), e.g. the suffix *-ccha-* as in *gácchati* 'goes' < PIE *g^w*m̥-sḱé-*.

[1] All roots and derivatives are from Whitney 1885 [1945].

[2] Etymologies based on *EWA* and *LIV*[2].

The Sanskrit palatal fricative *ś* is always clearly from the PIIr. primary palatal **ć* < PIE **ḱ*, e.g. *śay*/*śī* 'lie' < PIE **kei̯-*.

PIIr. **ǰʰ* < PIE **gʰ*/**gʷʰ* and **ǰʰ* < PIE **ǵʰ* both become Sanskrit *h*, e.g., *hánti* 'strikes, kills' < * *gʷʰén-ti* and *himá-* 'coldness, frost' < * *ǵʰi-mó-*. This glottal *h* falls outside the scope of this thesis and will not be further discussed.

For the roots themselves, there are mainly three allomorphic patterns concerning the root-final palatal/velar segments:

1. The root-final segment is always velar. This type of root must end with underlying velar segments /k/ synchronically in Sanskrit, which in turn go back to PIE (labio)velars. For examples, the root *tak-* 'rush' < PIE **tekʷ-* shows only velar segments throughout its attested forms, including the reported thematicized participle form *takantī* (attested in the Atharvaveda Paippalāda; *LIV²*, 620f) as well as the derivative form *-takana* (in Classical Sanskrit) with the strongly palatal-preferring suffix *-ana*.[3]

2. The root-final segment shows alternations between a palatal (*c*/*j*) and a velar (*k*/*g*). These final segments should go back to PIE (labio)velars as well. For *c*~*k* alternations, one could potentially assume an underlying /c/ becomes surface [k] under appropriate phonological conditions. For example, at the end of a word, we find *vā́k* NOM./VOC.SG.F of *vā́c-* 'voice' from the root *vac* 'speak' < PIE **u̯ekʷ-*; and before obstruents: *uk-tá-* 'spoken'. This distinction makes the underlying final palatal segment /c/ distinct from the underlying non-changeable velar segments /k/ in Sanskrit synchronic phonology.

3. The root-final segment shows alternations between palatal and retroflex segments. This type comes from the historical palatovelars. For example, the underlying /ś/ can synchronically have a retroflex realization in some contexts, e.g. *naṣ-ṭá-* 'lost' from the root *naś* 'be lost' < PIE **neḱ-*.

Problematic, however, is the voiced palatal *j*, which alternates either with velars or with retroflexes. Synchronically, there are already roots like *valg* 'spring' < PIE **u̯elg-* having a non-alternating /g/ that always surfaces as a velar. Therefore, it is hard to cleanly set up an underlying /g/ that undergoes synchronic palatalization for the roots that mostly show final voiced palatal segments. The only choice is an underlying palatal /j/. For the cases of palatal-retroflex

[3] See 5.4 *-ana*, *-anā*, *-ani/ī* and *-anīya*.

alternation, this would be fine parallel to /ś/, e.g. NOM./VOC.SG.M. *rā́ṭ* of *rā́j* 'king' < PIE *$h_3$reǵ-*, also in a compound: INS.PL.M. *samrā́ḍ-bhis* of *saṃ-rā́j* 'universal ruler'; but for the cases of *j~g* alternation, if one selects also an underlying /j/, but which behaves differently from the underlying /j/ showing palatal-retroflex alternations, there is a need to distinguish them, such as /j/^{1} and /j/^{2} as in Table 1. Such a distinction might be an argument for a kind of "gradient" degree of palatalness or velarness among at least the voiced segments.

Table 1: Proposed underlying representations of final velar/palatal segments in Sanskrit

UR \ SR	[k][4]	[c]	[ś/(c)ch]	[ṣ]	[ṭ/ḍ]	[g]	[j]
/k/	√	×	×	×	×	×	×
/c/	√	√	×	×	×	×	×
/ś/	√	×	√	√	√	×	×
/g/	√	×	×	×	×	√	×
/j/^{1}	√	×	×	×	×	√	√
/j/^{2}	√	×	×	√	√	×	√

Additionally, for most roots ending in palatal stops and some ending in velar stops, there are more alternations between palatal and velar segments that cannot always be immediately explained by a regular diachronic development. For example, the root *nij* 'wash' < PIE **nei̯g^w-* (in the full grade) as the last part of a compound with suffix *-a*, has three variants: *-neja*, *-neka* and *-nega*, but with suffix *-ana* (< PIE **-eno*, according to the *NIL*) only *néjana*, which might suggest different propensities of suffixes to cause palatalization; the root *bhuj* 'enjoy' < PIE **bheu̯g-* (in the full grade) with the suffix *-in*, has two variants: *bhojin* and *bhogin*, the latter seemingly contrary to the usual diachronic explanation.[5]

In this master's thesis I will first examine the data in Whitney 1885 [1945], including all roots with final palatal stop segments, as well as those with final velar stop segments, but showing alternations, to determine the propensities of each root to have final palatal/velar segments. I will further consider all the derivational suffixes contained in those derivatives,[6] in order to

[4] In sandhi, we observe the operation of a very common synchronic rule: Ved. *-kṣ-* < *k/g/c/j/ś-s-*, e.g. *a-k-ṣṇá* 'not fragmentary' from *aj/añj* 'bend' < PIE **$h_2$enk-*.

[5] *-nega* appears in the Brāhmaṇas and Sūtras, *-neka* appears in the Sūtras and Classical Sanskrit, *-neja* appears only in Classical Sanskrit; *bhogin* appears only in the Brāhmaṇas, *bhojin* only in Sūtras, which is then in fact later. Both imply a shift of this type of forms. For the puzzling *-neka*, Dr, Ryan Sandell suggests the following explanation: the allomorph with *-nek-* has been extracted from contexts where internal sandhi from a following /s/ or /t/ gives *-nek-*

[6] Those containing *-t-*, *-th-* and *-s-* are excluded as explained above.

determine the propensities of each suffix to induce palatalization/velarization at a synchronic level. The fundamental research question to be pursued is: to what extent does the distribution of root-final velar and palatal segments depend on (variable) synchronic phonological processes, and to what extent do the derivatives simply reflect historically inherited forms that show palatalization (or not) according to the Indo-Iranian secondary palatalization (as discussed above)?

2. Data and Methodology

2.1 Data Collection

First, I collected all the derivatives of the roots falling under the scope of the present investigation given in Whitney 1885 [1945], dividing them into two groups: those with final palatal segments and those with final velar segments, as shown in Appendix Tables 1.1.

Second, I categorized the suffixes based on their syllables, accentuation and stem patterns (e.g., vowel gradations). The derivatives of each suffix are also divided into two groups as above, as in Appendix Tables 1.2.

2.2 The Bayesian Logistic Regression Model

2.2.1 Preliminaries

Regression analysis is a common statistical method that can be used to explain the relationship between the response (dependent) variable and the (one or more) explanatory (independent) variable(s). In this thesis, for example, the dependent variable (Y) is the propensity for final palatal or velar segments, while the explanatory variables (x) are different roots and suffixes (the explanatory variables can range from categorical to ratio-scaled). In this case, the explanatory variables used are all categorical (factors with N levels, where N is the number of distinct roots or suffixes in the data).

Logistic regression is suitable for categorical response variables. Whether a derivative has a final palatal or velar segment can be regarded as one of two possible outcomes, which fits a binomial logistic model. In my models, I assigned a value of 1 to cases with final palatal segments and a value of 0 to cases with final velar segments.

The structure of a logistic regression model is as follows:

(1) $\hat{y} = \beta_0 + \beta_1 x_1 \dots \beta_n x_n$

(2) $f(x) = \frac{e^{(\beta_0 + \beta_1 x_1 \dots \beta_n x_n)}}{1 + e^{(\beta_0 + \beta_1 x_1 \dots \beta_n x_n)}} = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1 \dots \beta_n x_n)}}$

where

- equation (1) is the typical form of a multiple linear regression model;

- $\hat{y}$, more precisely written as $E(Y|x)$, is the expected value of the response variable Y (the outcome), which is conditional on the value of the explanatory variable x;
- β_0 is the optional intercept, the baseline coefficient for the value of Y before estimating the effects of x.
- β_1-β_n are the respective coefficients for the estimated effects for each explanatory variable (x_1-x_n) in the multiple regression model; here, n represents the total number of them;
- equation (2) is the same conditional mean of Y given x adapted to our logistic regression model;
- The coefficients above are estimated by the maximum likelihood method, for which we construct a likelihood function of the observed data but with unknown parameters; and then, an iterative algorithm tries multiple times the ultimate combination of values which is maximally close to the observed data (the maximum likelihood estimators) and return these values (summarized from Levshina 2015: 139–140; 253–276 and Hosmer et al. 2013: 1–33).

2.2.1 Model Details

Following Gelman et al. (2008), I chose a Bayesian logistic regression model, using the `bayesglm()` function from the `arm` package (version 1.14–4; Gelman et al. 2024) in R (Version 4.4.1; RStudio Development Team 2024) instead of the simple logistic regression by the function `glm()`, because of the small sample size and relative to number of the predictors. This model provides more stable and robust estimates of the intercept and all coefficients of binary categorical logistic regression predictors with appropriate independent Cauchy priors with center 0 and scale 2.5.

To obtain better arranged results from the nearest data, I followed the method in Sandell 2016. First, I used the `step()` function in R to get stepwise selected variables. Then, I apply the `bayesglm()` function to the separate data of both roots and suffixes. The results are in Appendix Tables 2.1 and 2.2. For both models, since the goal is to estimate the propensities of every root/suffix, I did not include an intercept as a reference.

With the help of Dr. Ryan Sandell, I also built up the model concerning the effects of both the roots and the suffixes (see Appendix Table 3). For this model with two sets of data, I used the `relevel()` function to specify the root *khañj* 'limp' and the suffix *-ita* (both having only one case of final palatal and velar segments) together as the intercept of this model, with which the AIC (the Akaike information criterion; higher AIC is positively associated with greater model complexity) is relatively small.

2.3 Results

2.3.1 Roots

The Bayesian regression result (Appendix Table 2.1) of all 86 roots (Appendix Table 2.1) shows that most roots prefer final palatal segments, although many do not go back to PIE palatovelars. This is perhaps unsurprising, if many original root-final (labio)velars are assumed to have been restructured as underlying palatal segments. There is a total of 18 roots exhibiting statistically significant preferences, as shown in Table 2.1, of which only *śak* 'be able' shows a visible propensity to have final velar segments with a negative coefficient estimate -1.41263.

Table 2.1: Statistically significant roots in the roots-only model

Root	**Estimate**	**Standard error**	***z* value**	**Prob(>|*t*|)**	**Propensity**	**Palatal Proportion**
aj 'drive'	2.21851	0.84305	2.632	0.00850	palatal	13/14≈92.9%
arc/ṛc 'shine, praise'	1.54360	0.57942	2.664	0.00772	palatal	16/19≈84.2%
ṛj/ṛñj/arj 'direct, stretch, attain'	2.42809	0.83862	2.895	0.00379	palatal	16/17≈94.1%
kuc/kuñc 'shrink, curl'	3.23760	1.52120	2.128	0.03331	palatal	9/9 = 100%
dhraj/dhrāj 'sweep'	2.96682	1.50525	1.971	0.04873	palatal	7/7 = 100%
pūj 'reverence'	2.96682	1.50525	1.971	0.04873	palatal	7/7 = 100%
prach 'ask'	3.11010	1.51311	2.055	0.03984	palatal	8/8 = 100%
bhrāj 'shine'	1.26256	0.59524	2.121	0.03391	palatal	12/15≈80%
muc 'release'	1.54360	0.57942	2.664	0.00772	palatal	16/19≈84.2%
yaj 'offer'	3.25759	0.83503	3.901	0.00010	palatal	36/37≈97.3%
yāc 'ask'	3.45682	1.53716	2.249	0.02452	palatal	11/11 = 100%
rac/rañj 'color'	1.26256	0.59524	2.121	0.03391	palatal	12/15≈80%
ruc 'shine'	1.25788	0.47757	2.634	0.00844	palatal	19/24≈79.2%
vaj 'be strong'	1.73718	0.86219	2.015	0.04392	palatal	8/9≈88.9%
vṛj 'twist'	2.00459	0.66236	3.026	0.00247	palatal	18/20 = 90%
vraj 'proceed'	3.23760	1.52120	2.128	0.03331	palatal	9/9 = 100%
śak 'be able'	-1.41263	0.58622	-2.410	0.01596	velar	3/17≈17.6%
sac 'accompany'	1.08863	0.53742	2.026	0.04280	palatal	13/17≈76.5%

However, in the model with both predictors (see Appendix Table 3), the situation is different. As is shown in Table 2.2, only 7 roots show statistical significance: *aj* 'drive' and *yaj* 'offer' show propensities to have final palatal segments; *iṅg* ‘stir’, *bhañj* ‘break’, *vic* ‘sift’, *yuj* ‘join’ and *śak* ‘be able’ show propensities to have final velar segments.

Notably, once the influence of suffixes is considered simultaneously, roots exhibiting velar propensities emerge, whereas the majority of roots listed in Table 2.1 are absent from Table 2.2. This suggests that most roots do not show genuine propensities to have final palatal segments and are instead influenced by the suffixes.

Table 2.2: Statistically significant roots in the two-predictor model

Root	Estimate	Standard error	*z* value	Prob(>|*t*|)	Propensity	Palatal Proportion
aj ‘drive’	2.30460	0.98901	2.330	0.01980	palatal	13/14≈92.9%
iṅg ‘stir’	-4.31725	1.45314	-2.971	0.00297	velar	1/4 = 25%
bhañj ‘break’	-2.53876	1.09670	-2.315	0.02062	velar	3/7≈42.9%
vic ‘sift’	-2.01763	0.99958	-2.018	0.04354	velar	3/6 = 50%
yaj ‘offer’	2.11249	0.96010	2.200	0.02779	palatal	36/37≈97.3%
yuj ‘join’	-1.81832	0.65479	-2.777	0.00549	velar	11/21≈52.3%
śak ‘be able’	-2.14545	0.83161	-2.580	0.00988	velar	3/17≈17.6%

2.3.1 Suffixes

I manually merged the original 211 suffix categories listed in Appendix Table 1.2 into just 102. For those that do not have different patterns with respect to vowel gradations and accentuation, I merged all types directly, e.g., all the X-*ana* types; for suffixes that couldn’t be merged directly (e.g., the X-*a* types), I merged them selectively, based on vowel gradations, accentuation, and, most importantly, based on the observed similarity in their propensity to cause palatalization or velarization.

The Bayesian regression result (Appendix Table 2.2) of the 102 suffixes shows that there are a total of 14 suffix types with statistical significance, as in Table 2.3. Among these, only (-)F́G-*a* and -*van* show a propensity to cause velarization, while the rest show a propensity to cause palatalization.

Noticeably, the pure root formation shows a clear palatal preference, similar to the abstract roots described by grammarians, most of which in a final palatal segment (see §5.1).

Table 2.3: Statistically significant suffixes in the suffix-only model

Root	Estimate	Standard error	*z* value	Prob(>|*t*|)	Propensity	Palatal Proportion

ROOT	3.44056	0.83615	4.115	$3.88e^{-5}$	palatal	43/44≈97.7%
(-)ZG-*a*	1.02727	0.49103	2.092	0.03643	palatal	15/20 = 75%
(-)F́G-*a*	-1.34032	0.59039	-2.270	0.02319	velar	3/16≈18.8%
-aka	4.86931	1.67612	2.905	0.00367	palatal	39/39 = 100%
-ana	3.52733	0.64466	5.472	$4.46e^{-8}$	palatal	81/83≈97.6%
-anīya	4.17455	1.60227	2.605	0.00918	palatal	21/21 = 100%
-ayitav(í)ya	3.23760	1.52120	2.128	0.03331	palatal	9/9 = 100%
-ayitṛ/ṛ́	3.64088	1.55224	2.346	0.01900	palatal	13/13 = 100%
-as	1.45920	0.51634	2.826	0.00471	palatal	19/23≈82.6%
-ā	2.29311	0.84125	2.726	0.00641	palatal	14/15≈93.3%
-i	2.26459	0.55556	4.076	$4.58e^{-5}$	palatal	33/36≈91.7%
-iṣṭha	3.23760	1.52120	2.128	0.03331	palatal	9/9 = 100%
-ya	1.26584	0.31846	3.975	$7.04e^{-5}$	palatal	44/56≈78.6%
-van	-1.85255	0.85624	-2.164	0.03050	velar	1/10 = 10%

The two-predictor model (see Appendix Table 3) shows rather more suffixes with velar propensities, as in Table 2.4. Many suffixes listed in Table 2.3: (-)ZG-*a*, *-anīya*, *-ayitav(í)ya*, *-ayitṛ/ṛ́*, *-as*, *-ā*, *-i*, *-iṣṭha* and *-ya* as showing palatal propensities then proved to be statistically insignificant, in part due to the inclusion of a marginally palatal-preferring intercept.

Table 2.4: Statistically significant suffixes in the two-predictor model

Root	**Estimate**	**Standard error**	***z* value**	**Prob(>|*t*|)**	**Propensity**	**Palatal Proportion**
ROOT	2.11503	0.88644	2.386	0.01703	palatal	43/44≈97.7%
(-)F́G-*a*	-2.88816	0.77410	-3.731	0.00019	velar	3/16≈18.8%
FG-*á*	-1.82969	0.6217	-2.943	0.00325	velar	8/19≈42.1%
-aka	3.74775	1.59101	2.356	0.01849	palatal	39/39 = 100%
-ana	2.61897	0.76880	3.407	0.00066	palatal	81/83≈97.6%
-in	-1.03945	0.48688	-2.135	0.03277	velar	23/38≈60.5%
-íya	-2.20814	1.03956	-2.124	0.03366	velar	1/6≈16.7%
-u	-1.85273	0.77208	-2.400	0.01641	velar	4/10 =40%
-ma	-2.73359	1.19734	-2.283	0.02243	velar	1/6≈16.7%
-man	-1.99644	0.87588	-2.279	0.02265	velar	3/11≈27.2%
-ra	-2.92116	0.80556	-3.626	0.00029	velar	5/15≈33.3%
-va	-3.53627	1.68081	-2.104	0.03539	velar	0/4 = 0%
-van	-3.25976	1.07676	-3.027	0.00247	velar	1/10 = 10%

Given that the two-predictor model is more sensitive to velar propensities, combining the two tables offers a more balanced perspective. Since the propensities for palatal segments are mostly influenced by the suffixes, the separate model focusing on suffixes serves as a relatively reliable source for identifying the palatal-causing suffixes.

Upon comparing the two tables, it is safe to assume that the majority of the palatal-preferring suffixes beginning with -*a*- continue a PIE *-*e*-. The root type is also not surprisingly palatal-preferring due to the choice of the lemma forms (see 5.1 Root Nouns). At the same time, one should not expect final palatal segments to appear before *v*, *m* and *r*, as well as the cases of (-)F́G-*a*- (a PIE suffix *-*o*- grade can be easily assumed) and -*u*, from the perspective of historical phonology.

The main problem that challenges the diachronic understanding lies in the other types with simple -*a*- suffixes and the cases with -*i*-. The clear velar propensity of (-)F́G-*a*- should be the case of all other simple -*a*-stem forms, which raises the question of why not all such forms are velar-preferring. Similarly, one would expect for the types with PIE **i* or**i̯* to regularly condition have final palatal segments, but there are also completely opposite examples which require a synchronic explanation.

2.3.1 Data Overview

In the two-predictor model there are several roots and suffixes having *p*-values slightly above the standard significance threshold of 0.05, but nonetheless fairly small (< 0.1). That their coefficient estimates do not register as statistically significant is in part due to a small number of examples and in part due to the choice of intercept. See Table 2.5:

Table 2.5: Roots and Suffixes with 0.05 < *p*-values < 0.1 in the two-predictor model

Root/Suffix	Estimate	Standard error	*z* value	Prob(>|*t*|)	Propensity	Palatal Proportion
uc 'be pleased'	-2.10252	1.18013	-1.782	0.07482	velar	13/14≈92.9%
(-)ŹG-*a*	-2.76534	1.60906	-1.719	0.08569	velar	0/3 = 0%
-FG-*a*(-)	-0.94560	0.52367	-1.806	0.07096	velar	20/34≈58.8%
F́G-*mya*	-2.87821	1.64703	-1.748	0.08055	velar	0/2 = 0%
LG-*a*	-2.79910	1.64853	-1.698	0.08952	velar	0/2 = 0%
LG-*á*	-1.56810	0.87266	-1.797	0.07235	velar	3/7≈42.9%
-*anā*	3.54619	2.07583	1.708	0.08758	palatal	4/4 = 100%
-*anīya*	2.96821	1.51698	1.957	0.05039	palatal	21/21 = 100%

Here, (-)ZG-*a* and the suffix -*anīya* are significant in the separate model and the *p*-value of -*anīya* is indeed really close to have statistical significance.

The regression model is also limited in addressing the roots and suffixes without obvious tendencies. This includes cases where the number of derivatives is simply too small to yield statistical significance, as well as a considerable number of suffixes that permit some amount of variation. While many of these suffixes don't have statistically significant propensities, their noteworthy behavior calls for further explanation. For these cases, a closer philological investigation provides a complementary perspective. These cases of substantially variable roots and suffixes will be discussed separately in Chapters 4 and 5.

3. The Regularity of Palatal and Velar Segments

3.1 Statistical Analyses of the Roots

Based on the two-predictor model (see Appendix Table 3), χ^2-tests for equality of proportions can be used to test the relationship between root propensities and the historical reconstruction of the root-final segment (using the `chiq.test()` function in R):

Table 3.1: Contingency table for palatal/velar propensities and the presence of PIE palatals

	Having a PIE palatal	**¬ Having a PIE palatal**	**Total**
Having a palatal propensity	12.5	19.5	32
Having a velar propensity	3	30	33
Total	15.5	49.5	65

For this and all subsequent tests, roots without certain etymologies in *LIV*[2] and *EWA* are excluded. Roots of disputed reconstruction are assigned a value of 0.5 instead of 1 or 0, for example, all secondary roots with *-*sḱé*- or -*ské*-[7] and *khañj* "limp" < **(s)keng/(s)keńg*.

This test shows an insignificant p-value of 0.39056 > 0.05, supporting the null hypothesis: roots ending in PIE palatal segments do not differ from those ending in PIE plain velars/labiovelars in their palatal propensities. This result is unsurprising, as is discussed above, although some roots ending in PIE palatal segments show propensities to have final palatal segments, the factor that mostly decides still appears to be the derivational suffix.

Table 3.2: Contingency table for palatal/velar propensities and the presence of PIE velars/labiovelars

	Having a PIE labiovelar	**Having a PIE velar**	**Total**
Having a palatal propensity	3	13	16

[7] See 4.10 Roots with the Suffix *-*sḱé*-.

Having a velar propensity	8	21	29
Total	11	34	45

In this test, similarly, the root *śak* ‘be able’ < **ḱek^(w)-* and the root *vraśc* ‘cut up’ < **u̯Resk^(w)* are attributed a value of 0.5.

For this set of data, the χ^2-test shows an insignificant p-value of 0.99286 > 0.05, supporting the null hypothesis: roots ending in PIE labiovelar segments do not differ from those ending in PIE plain velars in their velar propensities.[8]

Both tests confirm that there is no consistent diachronic relationship in Sanskrit between PIE final palatovelar, velar, or labiovelar segments and the velar/palatal propensities of roots at the global level. This suggests that the synchronic processes play a greater role in conditioning this observation.

3.2 Diachronic and Synchronic Concerns

Etymologically speaking, roots with PIE plain velars and labiovelars should not be listed with final palatal segments, nor should root nouns. It is likely that a restructuring process has occurred, which replaced the original velar segments with palatals.

Diachronically, suffixes beginning with front vocoids (including PIE **e*, **ē*, **i* or the glide **i̯*) caused diachronically palatalization of PIE plain velars and labiovelars, and they likely became palatal-inducing suffixes. For instance, the suffix *-ī* causes palatalization of the root *śak* ‘be able’, which has the strongest velar propensity of all roots, resulting in the form *śácī*.[9]

Similarly, suffixes such as (-)F́G-*a*, *-van*, *-ra* and so on, having historically expected velar outcomes, also became velar-inducing suffixes. For instance, the suffix *-ra* may be responsible for the depalatalization[10] of the root *mr̥j* ‘wipe’ < PIE **h₂merǵ-*,[11] which has a PIE final palatal segment, resulting in the form *-mr̥gra*. Thus, the opposite results with both kinds of suffixes may indicate influence from the roots or other processes of analogization.

[8] Although this set of data does not support the contrast between PIE labiovelars and plain velars, evidence from Clayton (2022) suggests that the distinction was preserved in environments of labialization of syllabic and consonantal rhotics within the Indo-Iranian family.

[9] The suffix *-ī* is, in fact, problematic, see also 5.12 *-ī*. There are also non-palatal cases like *kīm* (the indefinite enclitic particle) along with parallels in OAv. *čīm* and YAv. *čim* (*EWA*: 356f). This example shows that [ki:] can also occur as surface forms in a diachronically palatal environment, so the expected palatalization of the suffix *-ī* is not a strict rule but also acceptable.

[10] See See Kloekhorst (2011) on Weise’s Law and 5.13 *-ra*.

[11] See 4.4 *mr̥j* ‘wipe’.

Additionally, the systematic palatalization of plain velars and labiovelars could play a role in altering the underlying forms as plain palatals because the speakers couldn't distinguish them. The best examples of this are the root nouns (discussed in 5.1). Conversely, the unexpected appearance of velar segments for PIE palatals could be due to the replacement of roots or to the misunderstanding as having underlying velars/labiovelars. For example, *bhrāj* 'shine' < PIE *b^h*reh*$_1$*ǵ*- has an etymological final palatal segment, but it has a derivative form *bhárg-as*. Phonotactically, the sequence -*rj*- is quite common and the suffix -*as* has a propensity to cause palatalization even for PIE non-palatals, which indicates that there is an unexpected underlying [g]. Since its position of the ablauting vowel also differs, this form may simply have been replaced from another root or at least been influenced. There is an example of root replacement in Wackernagel and Debrunner 1954: §7d and §11cα: the form *ava-yā́ḥ* is actually from the root *yā* 'go' instead of *yaj* 'sacrifice', the replacement is due to the similarity of meaning–*ava-yā* 'avert by supplication' and *ava-yaj* 'atone through sacrifice'. For the example of the possible restructuring of the original underlying form from [j][2] to [g], see also 4.4 *mṛj* 'wipe'.

4. Etymological Discussion of Individual Roots

The goal of this chapter is to conduct a philological investigation on various roots to explain their propensities. The correlation between their etymologies and their actual propensities will determine whether diachronic or synchronic explanations are needed.

4.1 *aj* 'drive'

According to *LIV*^{2} (255f), the root *aj* is from PIE **h*$_2$*eǵ*-. The final PIE palatal contributes greatly to its propensity to have final palatal segments, as only 1 out of 14 cases of this root has a final velar segment is *agra*- 'foremost (part)' in the Vedas, which could be another case of depalatalization by Weise's Law (see 5.13), but its relation to this root is not certain.

4.2 *arc/ṛc* 'shine, praise'

This root is a great example of the synchronic process. According to *LIV*^{2} (240f), this root is from PIE **h*$_1$*erk*^{w}-. Although it ends with an etymological labiovelar, it has a significant palatal propensity in the separate model and an insignificant palatal propensity in the two-predictor model. Among its 19 cases, only 3 cases have final velar segments: *arká*-, *ṛkvá*- and *ṛ́kvan*-, which all have very strong velar-preferring suffixes. There is also the case of *arcín*, with the suffix -*ín*, which is surprisingly velar-preferring (see 5.9 below), but it nonetheless occurs here with a final palatal segment. One possible explanation is that this type of root is slightly more palatal-preferring due to its verbal stem formation. The class 1 present stem *arc-* could have influenced its full-grade derivative forms, making them more palatal-preferring regardless of the etymology.

4.3 *iṅg* 'stir'

This root has a strong propensity to have a final velar segment in the two-predictor model. Only 1 out of 4 cases of this root has a final palatal segment. According to *LIV²* (222f), the etymology of *iṅg* is **Hei̯g-*. The final velar segment of it is regularly palatalized as attested in Vedic: *éjati* 'moves, trembles' and dubitably *ejayant-* 'setting in motion' (Kāṭhaka Saṃhitā). Its propensity to have final velar segments can be attributed to its well-attested nasal present *iṅgáyati* 'sets in motion' < **Hi-n-g-éi̯e-*. In contrast, roots with PIE palatal palatalize the infix *-n-*, e.g. the root *rāj* 'be kingly' < PIE **h₃reǵ-* has its attested nasal present form in 3. PL. *r̥ñjate* 'move quickly forward in a straight line' < PIE **h₃r̥-n-ǵ-é-*. The infixed stem *iṅg-* was later recognized as a secondary root, thus we have forms like *iṅgati/te* (Dhātupāṭha), where palatal consonants are expected. Similarly, the velar propensities of the root *vic* 'sift' (**u̯eik-* , class 7 present *vinákti*) and the root *bhañj* 'break' (**bʰeg-* , class 7 present *bhanákti*) may also be attributed to their nasal present stems.

In conclusion, this root is secondary and able to permit a final velar segment even in the palatal-inducing environments like *iṅgana* (but also *iñjanā*) and *iṅgya*.

4.4 *mr̥j* 'wipe'

According to *LIV²* (280f), this root is from PIE **h₂merǵ-* 'shuffle, slip' rather from **h₂melǵ-* 'milk'. Among 13 attested cases of this root, the 4 velar cases are all followed by velar-inducing suffixes, namely: *-mārg-a* (possibly from PIE *-*o*), *-mā́rg-uka* (attested in the Brāhmaṇas), *-mr̥g-ra*, and *-mŕ̥g-van*.

Given that this root ends with an original palatovelar, one should not expect for /j/² to ever permit a surface velar. The only way to depalatalize it is Weise's Law (see 5.13). If Weise's Law is accepted, the existence of the allomorph *m(a)rg* in *mr̥g-ra-* might weaken the degree of "palatalness" of the root, opening up the possibility of further cases with a velar with other velar-inducing suffixes, as the examples above.

4.5 *vaj* 'be strong'

Although this root does not show statistical significance in the two-predictor model for its propensity to have final velar segments due to its small number of occurrences in the dataset, according to *LIV²* (660f), this root is from PIE **u̯eǵ-*, as the OP cognate is *vazạrka* (cf. also NP *buzurg* 'big'). The etymological palatal explains why this root only one case with a final velar segment has is *ugrá*, which is plausibly attributable to the depalatalization effect from the suffix *-ra*.[12]

4.6 *yaj* 'offer'

According to *LIV²* (224f), this root is from **Hi̯aǵ-*. Similarly, this root has a very strong propensity to have final palatal segments in both models. Its 36 cases have only 1 with final velar segments: *-yāga* together with its well attested parallel *-yāja*. The velar segment is unexpected for a PIE palatovelar and there is no evidence that compounding might affect the root-final segment, so this form remains unexplained.

4.7 *yāc* 'ask'

According to *LIV²* (310f), *yāc* is a secondary root from **i̯eh₂-k-*. Most of its derivatives are attested in the the Brāhmaṇas, and the earliest only as far as back to the Atharva Veda. As a later formed root, it had been quite palatal-preferring due to the already effective synchronic processes with its all 11 cases having final palatal segments. One interesting point is that even though it causes palatalization like roots from PIE palatals, it still behaves distinctively as the form *yāc-ñā́* vs. *praś-ná* shows. This means this root may have an underlying /c/² instead of formerly proposed /ś/ or /c/.

4.8 *yuj* 'join'

The root *yuj* is from **i̯eu̯g-* (*LIV²*: 316). This root shows an obvious propensity to have final velar segments in the two-predictor model with 10 out its 21 cases having final velar segments.

One possible explanation is that the class 7 present *yunákti* of this root could encourage a velar preference. Furthermore, Sandell (2015) employed statistical methods to prove the existence of the Obligatory Contour Principle (OCP) in early Indo-European languages, its constraint

[12] See 5.13 *-ra*.

prohibits identical elements in adjacent syllables. According to the formulation of this principle by Sandell, this principle may also be applied to explain the avoidance of identical place features. The two consonants of this root *y* [j] and *j* [ɟ] both have the feature [+ front], whereas *g* [g] does not. Thus, the velar propensity of this root may also be related to the residual effect of the OCP.

4.9 *śak* 'be able' and *śuc* 'gleam'

There is a major problem with the two roots which have the same etymological pattern: *śak* < **ḱek^(w)-* (*LIV*²: 322) and *śuc* < **ḱeu̯k-* (*LIV*²: 331). They may both have PIE final plain palatal segments. It is also possible that *śak* has a final labiovelar (see Chapter 3). They show different propensities: *śak* is strongly velar-preferring in both models, whereas *śuc* does not have such a tendency.

With respect to place of articulation, in the pattern of *CaC* having both consonants as palatal is still permissible, cf. root *śaś* 'leap' (which is very possibly a new denominal root abstracted from the noun *śaśa-* 'hare').

The possible etymological labiovelar alone also does not seem to make a difference as discussed in Chapter 3. Even if the labiovelar were significant, this explanation is not sufficient considering that this root has a much stronger propensity for final velar segments than other roots with PIE final labiovelars.

I would argue that *śak* has avoided restructuring in favor of a palatal, unlike most originally (labio)velar-final roots, possibly due to the influence of its nasal-infixed present stem. Parallels are *dagh* 'reach to' < PIE **dʰegʷʰh₂-*, *sagh* 'be equal to' < possibly PIE **segʷʰ-*, and *stigh* 'mount' < PIE **stei̯gʰ-*.[13] They all form class 5 present stems as *śak* with infix **-néu̯/-nu-*, and show only velar segments throughout their attested paradigms.[14] In contrast, the root *dāś* 'make offering' < PIE **deḱ-* also has the class 5 present *dāśnóti* but has *-ś-* before the nasal segment due to its PIE final palatal.

śak only shows final palatal segments only with suffix *-ī*, despite *-ī* being the expected strong velar-inducing suffix (see 5.12). Its variant root *śac* is limitedly attested in the Dhātupāṭha with class 1 present stem just like *śuc*: *śacate* 'is strong'.

[13] There is also the root *jagh* 'eat, devour', but it is late and uncertain.

[14] The root *stigh* 'mount' has 2 present forms: *stighnoti* and *stiṅnoti*. The latter has a final nasal but also velar sound.

4.10 Roots with the Suffix *-sḱé-

The suffix *-sḱé-* is very frequently used forming present stems (Lundquist & Yates 2018). In the data set there are several secondary roots with this suffix, and most of them show palatal propensities.

Table 4: Secondary Roots with the suffix *-sḱé-

Root	Etymology	Propensity in the separate model	Propensity in the two-predictor model
ich 'seek	*h$_2$is-sḱé-	Palatal	palatal
r̥ch 'go, send'	*h$_1$r̥-sḱé-	Palatal	palatal
prach 'ask'	*preḱ-sḱé-	Palatal	palatal
mūrch 'thicken'	*mr̥H-sḱé-	Palatal	velar
vāñch 'desire'	*wn̥H-sḱé-	Palatal	palatal
yach 'reach'	*ym̥-sḱé-	Palatal	palatal

The roots *r̥ch*, *vāñch* and *yach* each only have one example in the dataset, and therefore do not serving as clear cases of a palatal propensity. Only the root *mūrch* shows a velar propensity. Lubotsky (2001) suggested that the suffix may also go back to PIE *-ské-. However, as discussed in the Chapter 3, the etymological final palatal segment does not necessarily contribute to synchronic palatal propensities. Likewise, the PIE plain velar does not play a significant role. The velar propensity of *mūrch* may be related to its specific environment of its syllabic rhotic following a laryngeal.

5. Etymological Discussion of Individual Suffixes

This chapter also aims to correlate each root's etymology with its observed propensity and to provide the corresponding diachronic or synchronic explanation, thereby offering a complementary perspective on the overall data set.

5.1 Root Nouns

The root nouns almost always have final palatal segments[15]. However, according to Macdonell (1910: §297–303), there are actually two groups:

(1) Root nouns showing alternations between velar and palatal sounds, e.g., *vā́c-* 'speech' < PIE *u̯ek^w-, NOM./VOC.SG. *vā́k*, ACC.SG. *vā́cam*; *yuj-* 'associate' < PIE *i̯eu̯k-,

[15] The only exception, *luk* from the root *luñc* 'tear', is uncertain.

NOM./VOC.SG. *yuṅ(k)/yuk*, ACC.SG. *yuñjam/yujam*. This type has PIE plain velars or labiovelars.

(2) Root nouns showing alternations between retroflex and palatal sounds, e.g., *-pṛ́cch-* 'asking' < PIE **pṛḱ-sḱ-*, NOM./VOC.SG. *-pṛ́ṭ*, ACC.SG. *-pṛ́ccham*; *bhrā́j* 'shining' < PIE **b^hreh₁ǵ-*, NOM./VOC.SG. *bhrā́ṭ*, ACC.SG. *bhrā́jam*. This type has PIE palatals.

Under the Sanskrit grammarians' classification schema, the lemma forms always have final palatal segments, but this does not necessarily imply they are regarded as having underlying final palatal segments. Although etymological reflections exist in the NOM./VOC.SG. and before consonant-initial endings, the palatal segments have been largely imported, e.g., GEN.PL. *vācā́m*, the ending is from PIE **-oHom*, which should not cause palatalization.

The situation of the root nouns is a great example of how the underlying forms have been mixed and "falsely" analogized. This helps explain why it is difficult to find systematic etymological correlations among all the roots.

5.2 X-*a*

The suffixes with simple -*a* were originally divided into several groups based on different vowel gradations and accentuation as in Table 5. Most of them show velar propensities in the two-predictor model.

Table 5: Suffixes with -*a*

Root	Propensity in the suffix-only model	Propensity in the two-predictor model
(-)ŹG-*a*	velar	velar
(-)ZG-*a*	palatal	palatal
ZG-*á*	palatal	palatal
-FG-*a*(-)	palatal	velar
(-)F́G-*a*	velar	velar
FG-*á*	velar	velar
ĹG-*a*	no propensity	palatal
LG-*a*	velar	velar
-LG-*a*	palatal	velar
LG-*á*	velar	velar
Intens.Redup.-*á*	palatal	palatal

Etymologically, the suffix -*a*- should go back to the PIE thematic vowel *-*o*- (Lundquist & Yates 2018), which should cause velar propensities for all of the groups. Thus, a χ^2-test can be carried out to check if the X-*a* groups generally show a distinctive velar propensity among all the suffixes in the two-predictor model:

Table 6: Contingency table for root-final palatal/velar and the suffix type X-*a*/other suffixes

	X-*a*-	**¬ X-*a*-**	**Total**
Root-final palatal	62	472	534
Root-final velar	56	107	163
Total	118	579	697

This test shows $\chi^2 \approx 45.93947$ and a very significant p-value $\approx 0.00000 < 0.001$, supporting the alternative hypothesis that the X-*a* groups are more velar-preferring than the average level of the rest of the suffixes. This means, it is reasonable to view all the X-*a* groups, regardless of the stem types and accentuation.

Therefore, the only thing left to explain is the palatal propensities of several groups: (-)ZG-*a*, ZG-*á*, ĹG-*a* and Intens.Redup.-*á*. ĹG-*a* and Intens.Redup.-*á* have only two and three cases, respectively, and their propensities are not reliable due to their limited attested forms. (-)ZG-*a* has 20 attested forms, among which 12 cases happen to be from roots showing palatal propensities in the two-predictor model, in contrast to the significantly velar-preferring group (-)F́G-*a*, which has 8 out its 16 cases from velar-preferring roots. Thus, the palatal propensity of (-)ZG-*a* may be attributed to the coincidental distribution of roots.

ZG-*á* has 4 out 6 cases having final palatal segments, but among the 4 roots 3 have velar propensities. There are actually cases where a velar-preferring root has a final palatal segment following -*a* throughout all the groups, e.g., *śucá* (only in the Ṛgveda and Classical Sanskrit), *svajá* (in the Atharva Veda and the Brāhmaṇas) and *rucá* (only in the Brāhmaṇas). I propose one possible explanation that after the merger of PIE **e* and **o* in PIIr. (see Lubotsky 2018), the suffix -*a* could also have been regarded as from **e* or been influenced from -*a*- segments from other palatal-preferring suffixes, e.g. -*a*- from -*a-ka* (see 5.3) and then became palatal-inducing. This means the X-*a* group is at least split into two distinct suffixes, and the one regarded as from **e* is palatal-preferring. The process might have already begun in the Ṛgveda and spread to the later forms as the latter two examples.

5.3 -*aka*

According to Macdonell (1910: §116), this agent suffix can be divided as -*a-ka*. The latter part is from PIE *-*ko*-, cf. Gr. -κο-. The former part is more likely to be from *-*e*-, because this suffix has the strongest propensity to cause palatalization, having no case of final velar segments.

This suffix can be attached to lengthened grade, full grade and zero grade allomorphs of the root, which can be a complementary parallel to the complicated suffix patterns with -*a*- above.

5.4 -*ana*, -*anā*, -*ani*/*ī* and -*anīya*

The suffix -*ana* is likely from PIE *-*eno-*, which can best explain why this suffix has only 2 cases of final velar segments, along with the other 81 palatals. The Greek parallels with -νο- in Buck and Petersen 1945 do not have the -ενο- variants.

According to Macdonell (1910: §120–123), -*ana* along with -*anā* (having 4 cases of final palatal segments) and -*ani*/*ī* (having 2 cases of final palatal segments) are all suffixes forming action and agent nouns. The other two suffixes do not have large numbers but are very likely to have similar propensities as -*ana*.

According to Gotō, Klein and Sadovski (2015: §3.8.4 [6]), the gerundive suffix -*anīya* is from *-*ana*- + -*ī́ya*-. Its 21 cases all have final palatal segments, corresponding to this etymological explanation.

5.5 -*ayitav(i)ya* and -*ayitṛ/ṛ́*

The suffix -*ayitav(i)ya* has its all 9 cases having final palatal segments and the suffix -*ayitṛ/ṛ́* has its all 13 cases having final palatal segments. These two suffixes are from -*ay-i*- (from the causative basis -*aya*- < *-*éi̯e*-, Gotō, Klein and Sadovski 2015: §3.7.4) with the gerundive suffix -*tav(i)yà* and the agentive suffix -*tṛ* respectively (Gotō, Klein and Sadovski 2015: §3.8.4[5] and §1.2.6). The middle front vowel **e* is responsible for their palatal propensities.

5.6 -*as*

According to Höfler's conclusion (2012), the Indo-Iranian -*as* is either derived from the weak stem *-*H-es*- > PIIr. *-*as*- from the strong stem *-*H-s* > PIIr. *-*iš* (summarized from Schindler

1975), or from *-*os*. The latter case is due to the confusion of PIE **e* and **o* in Indo-Iranian, with the vowel *e* generalized throughout the paradigm, thus causing palatalization.

There are only 2 cases of velar segments in Avestan as parallels. *aogah*- 'power, strength' is only attested once in Yasna 29, 10, the remaining cases are all show the stem *aojah*- (the parallel in Vedic is *ójas*- ‘id.’; Nowicki 1975); also, YAv. *raēkah*- ‘leaving’ from the root *$le\underset{\frown}{i}k^w$- ‘to leave behind, to move away from’ (*LIV*^{2}: 406f), with its attested present form in YAv. *raēcaiieiti* ‘leaves’.

This explains why 19 out of the total 23 cases of the suffix -*as* show palatal segments. The remaining 4 cases: *áṅkas* ‘curve' and -*śokas* ‘flame', both are attested in the Ṛgveda; *ókas* ‘house’ and *bhárgas* ‘radiance’[16] both in the Vedas. This suggests that they may be early remnant forms like *aogah*-.

In conclusion, this is a palatal-conditioning suffix in Vedic, and all the instances of velar segments preceding -*as*- are inherited archaisms.

5.7 -*ā*

This suffix is likely from PIE *-eh_2-, cognate with Gr. -η, having a strong palatal propensity with all its 14 cases having final palatal segments.

However, the root *g^weh_2- ‘put the foot down, step’ (*NIL*: 174f) presents a counterexample. All of its full grade stems only have velar segments, e.g. *gātú*- ‘path, way’ < *g^wah_2-*tu*-. This root shows the regular outcome of *-eh_2-. Because laryngeal coloring (*-eh_2- →*-ah_2-) already took place in PIE (Byrd 2018), thus it should have been restructured to have the new underlying representation /-ah_2-/ and thus should not have caused palatalization like the simple PIE vowel **e* in PIIr.

Back to -*ā*, the reason why this suffix shows a palatal propensity may be related to its attested forms. Interestingly, no matter what propensities these roots have, they all have final palatal segments. This suffix is first attested comparatively late; only the case *sácā* is attested in the

[16] Though this explanation does not work for *bhárgas*- if it indeed contains a root with an original palatovelar. See also Chapter 3.

Ṛgveda, while all of the other cases date from the Brāhmaṇas to even Epic Sanskrit. It is possible that after the vowel merger this suffix is regarded later as from *$\bar{e}$ which triggers palatalization.

5.8 -*i*

The simple suffix -*i* < *-*i*- has a positive coefficient and is palatal-inducing (but only significant in the suffix-only model) with 22 out 55 of its forms showing final palatal segments. The only 3 cases having velar propensities are likely to have underlined /k/ or /g/: *bhaṅgi*, -*bhogi* and sákhi (uncertain).

5.9 -*in*

This root shows a clear propensity to cause velarization in the two predictor model, which is unexpected given the vowel -*i*-.

Grestenberger (2021) proposed two possible derivational chains for suffix -*ín* (in Vedic always accented), with all steps within each attested, the original examples are as follows:

(1) PIIr. *(-)*áću̯-a*- 'horse' (Ved. *áśva*-) (PIE *-*o*-) → adjectival **(-)aću̯-á*- 'with/having horses' (PIE **ó*-adjectives, possessive or not) → substantival **aću̯-í*- 'one with/who has horses' (**í*-substantivization) → substantival/adjectival **aću̯-í-n*- 'one who has horses (m.); with/having horses (adj.)' (recharacterization with *-*n*- and then reanalyzation)

(2) Ved. *śā́ka*- m. 'strength' → adjectival *śāká*- 'strong one' (PIE **ó*-adjectives, possessive or not) → substantival/adjectival *śākín*- 'strong one'; adj. 'strong' (in Vedic -*ín*- already used together as an substantival suffix then reanalyzed as adjectival)

The suffix type -*in* has 23 cases with palatal segments and 14 with velar segments. Both derivational chains end with (*)*i*, which as a front vowel should definitely cause palatalization of the final velar segments of the roots. Although Grestenberger excluded the possessive "Hoffmann suffix" *-*Hon*- as underlying Indo-Iranian *-*ín*- on phonological and derivational grounds, this is the most feasible hypothesis for the many velar cases. Therefore, this suffix requires further research to find a better explanation. The following discussions of -*íya* and -*ī* regarding their derivational features, which do not trigger palatalization, may be related.

5.10 *-íya*

This suffix is written as *-yà* (lemma *-ya-*) and is very commonly used to form nominal derivatives and gerundives (Wackernagel and Debrunner 1954: §633–670). According to Gotō, Klein and Sadovski 2015: §3.8.4[1], its etymology is **-i̯i̯a-* < **-ih₂o-*?. Surprisingly, it has a strong velar propensity with 4 out of its cases having final velar segments despite beginning with a front vocoid. For this suffix, the original root's propensity does not appear to be the most decisive factor, e.g., *bhojyà* 'to be enjoyed' from the root *bhuj*[2] 'enjoy' < **bheu̯g-* which has a velar propensity and *-vargyà* 'belonging to, connected to' from the root *vr̥j* 'twist' < **h₂u̯erg-* which has a palatal propensity.

The explanation for this phenomenon is that this root doesn't alter the original basis of the stem. The traditional term for this is *luk*, meaning that only the original affix drops out, the secondary derivative's original stem remains unchanged, and only the new suffix is added. For example, *gārgya-* 'pertaining to Garga' derives from *garga-* 'Garga' (the sage's name): the last *-g-* segment in the derivative reflects the influence from the original affix *-a-* (very likely < PIE **-o-*) and does not get palatalized (Wackernagel & Debrunner 1954: § 13b).

In conclusion, this derivative-forming suffix does not show expected effect of palatalization but only attaches to the unchanged original stems, showing a statistical velar propensity as a consequence.

5.11 *-iṣṭha*

Luján (2019) concluded that this suffix is from **-is-to-*, cognate with Av. *-išta*, Gr. -ιστος, and Goth. *-ista-* < PGmc. **-istaz*. Lundquist and Yates (2018) rejected the reconstruction of **-isth₂o-* (which would explain the aspiration in Vedic) due to a lack of evidence. However, Luján mentions in Prósper 2018 that certain Continental Celtic names ending in *-isso-* could potentially originate from the similar superlative forms in **-ist(H)o-*.

This suffix has a strong propensity to cause palatalization in the separate model with all of its 9 cases all having final palatal segments because of the etymological front vowel **-i-*. This together with the case of the simple -i suffix, makes an contrast with *-ín-* above: certain original */i/ comes to be palatal-preferring, but *-ín-* is not.

5.12 -*ī*

The suffix -*ī* has only 5 cases and is reported to have an insignificant velar propensity. The only two velar cases are *śā́kī* (uncertain) and *mokī.*

In Whitney's concordance (1885 [1945]), *mokī* is listed together with *moka* (both attested in the Vedas), suggesting their derivative relationship. According to Kim (2014), the etymology of this suffix is *-*ih*$_2$, which forms Indo-European possessive-instantial derivatives and was later grammaticalized as a feminine marker. Wackernagel and Debrunner (1954: §243–256) already noticed that -*ī* is a highly productive suffix forming secondary derivatives from the same stems as the previous suffixes like -*íya* (see 5.10), e.g., -*kī* is simply derived from -*ka*, but here the -*ī* does not palatalize the previous velar at all. The suffix -*ī* is also commonly used to build verbal compounds in a similar way, known as the *cvi*-construction, e.g. *aṅkī-kṛ*- 'embrace' from the noun *aṅka*- 'curve (of the body); bend in the arm'(Balles 2006: §2.2.3.1 and Whitney 1896: 1093f). The logic is simple: as a very productive secondary suffix in Sanskrit, it should clearly reflect its original stem. Thus, it simply attaches to the original stem without altering its final velar consonant just as the other final consonants which aren't affected by it, so the palatalization effect should not arise.

To sum up, this suffix's potential velar propensity may reflect its function of forming secondary derivatives, in which context faithfulness to the segment of the base prevails.

5.13 -*ra*

The suffix -*ra* has 5 cases with final palatal segments and 10 cases with final velar segments, and is reported to have a propensity to have final velar segments by the two-predictor model.

Kloekhorst (2011) examined the Indo-Iranian data and concluded that they support the assumption of a sound change in Indo-Iranian labeled as Weise's Law:

$$\{*\acute{k}, *\acute{g}, *\acute{g}^h\} \rightarrow \{k, g, g^h\} \;/\; \_\_*r$$

Based on Kloekhorst's (2011) conclusion, this rule doesn't apply to *-*ri*. In addressing the other exceptions, aside from those explainable by analogy to full-grade forms, Kloekhorst failed to explain the exceptions by morpheme boundaries because the palatalization effect should not be hindered. Overall, this effect of depalatalization correlates with the propensity of the suffix -*ra* < PIE *-*ró*-.

5.14 -*va* and -*van*

According to Gotō, Klein and Sadovski (2015: §2.1.3 and §1.2.7.1), this suffix -*va* derives from PIIr. *-*u̯a*- and suffix -*van* is likely from the proterokinetic diagram of *-*u̯r̥*/-*u̯én*- (cf. YAv. NOM. SG. *θan-uuarᵊ* ABL. *θan-uuan-āṯ*). They both have propensities to cause velarization due to the influence of the back approximant *-*u̯*-, as all 4 cases of -*va* and 9 out of 10 cases of -*van* exhibit final velar segments.

6. Conclusions

This thesis has focused on the final velar-palatal alternations of root-final segments in the Sanskrit derivatives, trying to determine the velar/palatal propensities of the targeted roots and suffixes as well as which processes (diachronic/synchronic) are responsible for them.

Using a Bayesian logistic regression model, I obtained both the separate results for the roots and suffixes, as well as a result taking account of the effects of both simultaneously. Describing roots and suffixes as having different extents of velar/palatal propensities fit the data well with multiple cases. Philological concerns help deal with the cases which the statistical models fail to explain due to the limited numbers.

For the roots, the results show that most roots do not show significant palatal propensities, which are instead mostly under the influence of the suffixes. There are also, unsurprisingly, no systematic diachronic correlations between the velar/palatal propensities and the PIE plain velar/labiovelar/palatovelar segments. In the end, synchronic explanations are perhaps responsible for most of the cases.

For the suffixes, a number of their behaviors ae explainable through a diachronic lens. However, some of them need synchronic explanations due to the later phonological changes or due to their use in secondary derivatives, where the original stems do not tend to undergo any alternation. Thus, all the suffixes can be categorized as velar-inducing or palatal-inducing, to some extent.

Notably, ten of the twelve roots with confirmed PIE palatovelars exhibit a palatal tendency, though mostly insignificant. This suggests that one can also exclude roots ending in PIE palatovelars to better estimate the overall effect of the suffixes. I have tried to make this model but applying a similar scheme I didn’t get any different significant results. For future models, I suggest trying different combinations of roots and suffixes to find an intercept that reveals more subtle propensities.

Appendix

1 The original data collected from Whitney 1885 [1945]

Table 1.1: Counts of derivatives containing final palatal and velar segments by root

Root	# Final Palatal Segment	# Final Velar Segment
ac/añc 'bend'	5	3
aj 'drive'	13 (with 1 case listed as unsure)	1 (listed as unsure)
añj 'anoint'	8	2
arc/ṛc 'shine, praise'	16	3
āñch? 'tear'	1	0
iṅg 'stir'	1	3
iṣ → *ich* 'seek'	3	0
uc 'be pleased'	2	4
*ujh** 'forsake'	3	0
*uñch** 'glean'	2	0
ubj? 'force'	2	1 (listed as unsure)
ṛ → *ṛch* 'go, send'	1	0
ṛj/ṛñj/arj 'direct, stretch, attain'	16	1
ṛj 'shine'	4	0
ej/īj 'stir'	2	0
kuc/kuñc 'shrink, curl'	9	0
*kūj** 'hum'	3	0
khañj 'limp'	2	0
kharj 'creak'	1	1
garj 'roar'	4	0
guñj 'hum'	2	0
*carc** 'repeat'	5	0
tañc/tac 'coagulate'	1	4
tarj 'threaten'	3	0
tij 'be sharp'	5	3 (with 1 case listed as unsure)
tuc 'impel, generate'	1	4 (with 1 case listed as unsure)
tuj 'urge, thrust'	5	3 (with 1 case listed as unsure)
tyaj 'forsake'	9	2
dhraj/dhrāj 'sweep'	7	0
nij 'wash'	5	2
pac 'cook'	12 (with 1 case listed as unsure)	4
paj? 'start'	2	0
pūj 'reverence'	7	0
pṛc 'mix'	2	1
prach 'ask'	8	0
bhaj 'divide, share'	13	5
bhañj 'break'	3	4
bhiṣaj 'heal'	2	0

bhuj[1] 'bend'	5 (with 1 case listed as unsure)	1
bhuj[2] 'enjoy'	14	5
bhṛjj 'roast'	2	0
bhrāj 'shine'	12 (with 2 cases listed as unsure)	3 (with 1 case listed as unsure)
majj 'sink'	5 (with 2 cases listed as unsure)	1 (listed as unsure)
mañj? 'purify'	2 (with 1 case listed as unsure)	0
muc 'release'	16	3
mūrch 'thicken'	2	1
mṛc 'injure'	2	2
mṛj 'wipe'	9	4
mruc/mluc 'set'	7	1
mlech 'speak barbarously'	1	0
yaj 'offer'	36	1
yam → *yach* 'reach'	1	0
yāc 'ask'	11	0
yuj 'join'	11	10
rac 'produce'	6	0
rac/rañj 'color'	12 (with 2 cases listed as unsure)	3
rañch 'mark'	1	0
rāj 'be kingly'	6	0
ric 'leave'	8	5
ruc 'shine'	19 (with 1 case listed as unsure)	5
ruj 'break'	6	3 (with 1 case listed as unsure)
lajj 'be ashamed'	1	0
lāñch 'mark'	2	0
luñc 'tear'	3	1 (listed as unsure)
loc 'see, consider'	5	0
vac 'speak'	16	9 (with 2 cases listed as unsure)
vaj 'be strong'	8	1
vañc 'move crookedly'	5	5
vāñch 'desire'	1	0
vic 'sift'	3	3
vij 'tremble'	5	2 (with 1 case listed as unsure)
*vīj/vyaj** 'fan'	2	0
vṛj 'twist'	18 (with 1 case listed as unsure)	2
*vyac/vic** 'extend'	3 (with 1 case listed as unsure)	0
vraj 'proceed'	9	0
vraśc 'cut up'	3	3 (with 1 case listed as unsure)
śak 'be able'	3 (with 1 case listed as unsure)	14 (with 1 case listed as unsure)
*śiñj** 'twang'	2 (with 1 case listed as unsure)	0
śuc 'gleam'	14	9 (with 1 case listed as unsure)
śvañj 'spread'	0	1
sac 'accompany'	13 (with 1 case listed as unsure)	4 (with 1 case listed as unsure)
saj/sañj 'hang'	7	3
sic 'pour out'	8	3

sṛj ‘send forth’	9	2
sphūrj ‘rumble’	5	0
svaj/svañj ‘embrace’	5	2

Table 1.2: Counts of derivatives containing final palatal and velar segments by derivational affix

Stem-Suffix	**# Final Palatal Segment**	**# Final Velar Segment**
(-)F́G/FG(root)(-)	11 (with 2 cases listed as unsure)	0
(-)ĹG/LG(root)(-)	9	0
(-)ŹG/ZG(root)(-)	22	1 (listed as unsure)
(-)ŹG-*a*	0	3 (with 2 cases listed as unsure)
-ZG-*a*	8 (with 1 case listed as unsure)	3 (with 1 case listed as unsure)
ZG-*a*	7	2 (with 1 case listed as unsure)
ZG-*á*	4	2
-FG-*a*	12	8
-F́G-*a*	2	5
F́G-*a*	1	8
FG-*a*(-)	8 (with 1 case listed as unsure)	6
FG-*á*	8	11 (with 2 cases listed as unsure)
ĹG-*a*	1	1
LG-*a*	0	2
-LG-*a*	6	1
LG-*á*	3	4
ZG-*ā*	6	0
-ZG-*ā*	2	0
F́G-*ā*	1	0
FG-*ā*	4	0
FG-*ā́*	1	0
LG-*ā*	0	1
(-)ZG-*as*	1	0
(-)F́G-*as*	10 (with 1 case listed as unsure)	3
-FG-*as*	1	1
FG-*as*(-)	2 (with 1 case listed as unsure)	0
FG-*ás*	2	0
ĹG-*as*	3	0
LG-*aná*	1	0
ĹG-*ana*	2	0
(-)LG-*ana*	10	0
FG-*aná*	3	0
(-)FG-*ana*	28	1
(-)F́G-*ana*	20	0
(-)ZG-*ana*	15	1
ŹG-*ana*	1	0
ZG-*ána*	1	0
LG-*anā*	1	0

ZG-*anā*	1	0
FG-*anā*	2	0
ZG-*ā́nā*	1	0
ZG-*iná*	1	0
FG-*anā́nas*	1	0
(-)FG-*anī/ī́ya*	16	0
(-)LG-*anīya*	4	0
ZG-*anīya*	1	0
FG-*iṣṇu/ú*	2	0
LG-*iṣṇu*	2	0
-FG-*ayiṣṇu*	1	0
ZG-*rá*	1	3
Ź G-*ra*	0	1
-ZG-*ra*	0	1
ZG-*ira*	1	0
F́G-*ra*	2	1 (listed as unsure)
FG-*ra*	0	1
FG-*rá*	1	2
-FG-*ra*	1 (listed as unsure)	1
FG-*irá*	1	0
ZG-*lá*	0	1
F́G-*ri*	0	1
-FG-*ara*	1	0
ZG-*ā́ra*	1	0
(-)LG-*aka*	9	0
(-)FG-*aka*	22	0
(-)ŹG/ZG-*aka*	8	0
-ZG-*īká*	1	0
ŹG-*ika*	1	0
F́G-*uka*	1	0
(-)ĹG-*uka*	1	1
FG-*ūka*	1	0
Intens.Redup.-*ū́ka*	1	0
ZG-*ma*	0	1
ZG-*má*	0	2
FG-*má*	0	1
F́G-*ma*	1	1
ĹG-*man*	0	1
F́G-*man*	1	4 (with 1 case listed as unsure)
FG-*mán*	1	1
-ŹG-*man*	0	1
ZG-*mán*	1 (listed as unsure)	1
ZG-*aya/á*	2	0
-FG-*aya*	1	1
LG-*ayá*	1	0
ZG-*ayā́*	1	0
ZG-*yā*	1	0

(-)FG-*ya/ā́*	2	1
LG-*íyā*	1	0
FG-*atíya*	1	0
ZG-*ipyá*	1	0
ZG-*īpín*	1	0
(-)ŹG/ZG-*ya*	14	2
(-)FG-*íya*	1	4
(-)F́G/FG-*ya*	22	8
(-)ĹG/LG-*ya*	8	2
LG-*íya*	0	1
ŹG-*u*	0	1 (listed as unsure)
ZG-*u*	1	0
-ZG-*u*	1	0
ZG-*ú*	1	0
FG-*ú*	0	2 (with 1 case listed as unsure)
FG-*u-*	0	1
F́G-*u*	0	1
-ĹG-*u*	0	1
LG-*īyas*	0	1
F́G/FG-*īyas*	4	0
(-)ŹG/ZG-*īyas*	2	0
ŹG-*i*	4 (with 1 case listed as unsure)	0
ZG-*i*	2	0
-ZG-*i*(-)	4	0
ZG-*í*	2	0
F́G-*i*	2	1 (listed as unsure)
FG-*i*	2	1
*FG-*i*	4	0
FG-*í*	4	0
F́G-*i-*	1	0
FG-*i-*	0	1
(-)LG-*í*	4 (with 1 case listed as unsure)	0
ĹG-*i*	1	0
LG-*i*	2 (with 1 case listed as unsure)	0
-LG-*in*	5	2
LG-*in*	4	2
ZG-*in*	1	0
-ZG-*in*	1	0
FG-*ín*	1	0
FG-*in*	4	4
-FG-*in*	7	6
ĹG-*ī*	0	1
(-)F́G/FG-*ī*	2	1
-ZG-*ī*	1	0
LG-*is-*	1	0
FG-*ís*	3	0
ZG-*is-*	1	0

ĹG-*iṣṭha*	1	0
ŃG-*iṣṭha*	7	0
-ZG-*iṣṭha*	1 (listed as unsure)	0
FG-*átha*	2	0
ZG-*átha*	1	0
(-)FG-*itṛ*	3	0
LG-*itṛ*	1	0
(-)FG-*ayitṛ/ṛ́*	9	0
(-)LG-*ayitṛ*	3	0
ZG-*ayitṛ*	1	0
ŃG/FG-*atra*(-)	2	0
FG-*átri*	1	0
ZG-*iti*	1	0
ŹG-*īti*	1	0
ZG-*īṣá*	1	0
FG-*vin*	2	0
FG-*vá*	0	1
ŹG-*va*	0	1
ZG-*vá*	0	2
ZG-*ūnas*	1	0
ŃG-*una*	1	0
ŃG-*van*	1	2
(-)ŹG/ZG-*van*	0	7
FG-*vaná*	0	1
Des.Redup.-*vaná*	0	1
Des.Redup.-*váni*	0	1
FG-*vanú*	0	1
ŹG-*vas*	0	1
ZG-*íśvan*	1	0
FG-*ivā́ṃs*	0	1
-ZG-*athu*	1	0
FG-*áthu*	1	0
LG-*itavya*	1	0
FG-*itavya*	2	0
ZG-*itavya*	1	0
LG-*ayitavi/íya*	2	0
FG-*ayitavya*	6	0
ZG-*ayitavya*	1	0
ZG-*itá*	0	1
LG-*ita*	1	0
FG-*álā*	0	1
FG-*ū́ra*	1	0
(-)Des.Redup.-*iṣu*	3	0
Caus.Redup.-*i*	1	0
(-)FG-*ati*	2	0
FG-*atá*	3	0
FG-*elima*	1	0

FG-*ná*	2	0
LG-*nā́*	1	0
LG-*nyá*	1	0
-FG-*nya*	1	0
Perf.Redup.-*u*	1	0
Intens.Redup.(root)	1	0
Intens.Redup.-*á*	2	0
Intens.Redup.-*énya*	1	0
FG-*enya*	1	0
LG-*ayú*	1	0
-FG-*anu*	1	0
FG-*urá*	0	1
F́G-*yu*	1	0
ZG-*yu/ú*	2	0
ZG-*iṣíya*	1	0
ZG-*iṣya*	1	0
LG-*āra*	1	0
LG-*ālíya*	1	0
-FG-*alya*	1	0
F́G-*us*	1	0
FG-*ani/ī*	1	0
ZG-*anī́*	1	0
ĹG-*an*	1	0
LG-*án*	1	0
FG-*án*	1	0
F́G-nas	0	1
-ZG-*atnu*	1	0
ŹG-*mant*	0	1
ŹG-*ant*	1	0
FG-*nú*	0	1
F́G-*mya*	0	2 (with 1 case listed as unsure)
FG-*át*	1	0

Here, a dash (-) generally marks a morphological boundary. When it precedes the stem, it indicates this combination is at the end of a compound.

2 The Bayesian logistic regression results

Table 2.1: Bayesian logistic regression model for the roots

Root	Estimate	Standard error	*z* value	Prob(>|*t*|)	Significance
ac/añc ‘bend’	0.44293	0.67500	0.656	0.51170	
aj ‘drive’	2.21851	0.84305	2.632	0.00850	**
añj ‘anoint’	1.21119	0.70504	1.718	0.08582	.
arc/ṛc ‘shine, praise’	1.54360	0.57942	2.664	0.00772	**
āñch ‘tear’	1.20165	1.64372	0.731	0.46474	
iṅg ‘stir’	-0.83291	0.95369	-0.873	0.38247	

iṣ → ich ‘seek’	2.10557	1.49908	1.405	0.16015	
uc ‘be pleased’	-0.57524	0.77594	-0.741	0.45848	
*ujh** ‘forsake’	2.10557	1.49908	1.405	0.16015	
*uñch** ‘glean’	1.73754	1.53087	1.135	0.25637	
ubj? ‘force’	0.49982	1.01501	0.492	0.62242	
ṛ → ṛch ‘go, send’	1.20165	1.64372	0.731	0.46474	
ṛj/ṛñj/arj ‘direct, stretch, attain’	2.42809	0.83862	2.895	0.00379	**
ṛj ‘shine’	2.38644	1.49132	1.600	0.10955	
ej/īj ‘stir’	1.73754	1.53087	1.135	0.25637	
kuc/kuñc ‘shrink, curl’	3.23760	1.52120	2.128	0.03331	*
*kūj** ‘hum’	2.10557	1.49908	1.405	0.16015	
khañj ‘limp’	1.73754	1.53087	1.135	0.25637	
kharj ‘creak’	-0.00000	1.14360	-0.000	1.00000	
garj ‘roar’	2.38644	1.49132	1.600	0.10955	
guñj ‘hum’	1.73754	1.53087	1.135	0.25637	
*carc** ‘repeat’	2.61330	1.49274	1.751	0.08000	.
tañc/tac ‘coagulate’	-1.08539	0.91844	-1.182	0.23730	
tarj ‘threaten’	2.10557	1.49908	1.405	0.16015	
tij ‘be sharp’	0.44293	0.67500	0.656	0.51170	
tuc ‘impel, generate’	-1.08539	0.91844	-1.182	0.23730	
tuj ‘urge, thrust’	0.44293	0.67500	0.656	0.51170	
tyaj ‘forsake’	1.32386	0.69645	1.901	0.05732	.
dhraj/dhrāj ‘sweep’	2.96682	1.50525	1.971	0.04873	*
nij ‘wash’	0.77423	0.74916	1.033	0.30139	
pac ‘cook’	1.01140	0.54285	1.863	0.06244	.
paj? ‘start’	1.73754	1.53087	1.135	0.25637	
pūj ‘reverence’	2.96682	1.50525	1.971	0.04873	*
pṛc ‘mix’	0.49982	1.01501	0.492	0.62242	
prach ‘ask’	3.11010	1.51311	2.055	0.03984	*
bhaj ‘divide, share’	0.88896	0.50059	1.776	0.07577	.
bhañj ‘break’	-0.24569	0.70400	-0.349	0.72710	
bhiṣaj ‘heal’	1.73754	1.53087	1.135	0.25637	
bhuj[1] ‘bend’	1.28926	0.89605	1.439	0.15020	
bhuj[2] ‘enjoy’	0.96046	0.49550	1.938	0.05258	.
bhṛjj ‘roast’	1.73754	1.53087	1.135	0.25637	
bhrāj ‘shine’	1.26256	0.59524	2.121	0.03391	*
majj ‘sink’	1.28926	0.89605	1.439	0.15020	
mañj? ‘purify’	1.73754	1.53087	1.135	0.25637	
muc ‘release’	1.54360	0.57942	2.664	0.00772	**
mūrch ‘thicken’	0.49982	1.01501	0.492	0.62242	
mṛc ‘injure’	-0.00000	0.88231	-0.000	1.00000	
mṛj ‘wipe’	0.73712	0.56552	1.303	0.19243	
mruc/mluc ‘set’	1.60773	0.87010	1.848	0.06464	.
mlech ‘speak barbarously’	1.20165	1.64372	0.731	0.46474	
yaj ‘offer’	3.25759	0.83503	3.901	0.00010	***

yam → yach ‘reach’	1.20165	1.64372	0.731	0.46474	
yāc ‘ask’	3.45682	1.53716	2.249	0.02452	*
yuc ‘join’	0.08997	0.42448	0.212	0.83213	
rac ‘produce’	2.80338	1.49812	1.871	0.06131	.
rac/rañj ‘color’	1.26256	0.59524	2.121	0.03391	*
rañch ‘mark’	1.20165	1.64372	0.731	0.46474	
rāj ‘be kingly’	2.80338	1.49812	1.871	0.06131	.
ric ‘leave’	0.42877	0.54214	0.791	0.42901	
ruc ‘shine’	1.25788	0.47757	2.634	0.00844	**
ruj ‘break’	0.60804	0.65400	0.930	0.35251	
lajj ‘be ashamed’	1.20165	1.64372	0.731	0.46474	
lāñch ‘mark’	1.73754	1.53087	1.135	0.25637	
luñc ‘tear’	0.83291	0.95369	0.873	0.38247	
loc ‘see, consider’	2.61330	1.49274	1.751	0.08000	.
vac ‘speak’	0.54717	0.40481	1.352	0.17647	
vaj ‘be strong’	1.73718	0.86219	2.015	0.04392	*
vañc ‘move crookedly’	-0.00000	0.59732	-0.000	1.00000	
vāñch ‘desire’	1.20165	1.64372	0.731	0.46474	
vic ‘sift’	-0.00000	0.74664	-0.000	1.00000	
vij ‘tremble’	0.77423	0.74916	1.033	0.30139	
*vīj/vyaj** ‘fan’	1.73754	1.53087	1.135	0.25637	
vṛj ‘twist’	2.00459	0.66236	3.026	0.00247	**
*vyac/vic** ‘extend’	2.10557	1.49908	1.405	0.16015	
vraj ‘proceed’	3.23760	1.52120	2.128	0.03331	*
vraśc ‘cut up’	-0.00000	0.74664	-0.000	1.00000	
śak ‘be able’	-1.41263	0.58622	-2.410	0.01596	*
*śiñj** ‘twang’	1.73754	1.53087	1.135	0.25637	
śuc ‘gleam’	0.41872	0.41493	1.009	0.31291	
śāvañj ‘spread’	-1.20165	1.64372	-0.731	0.46474	
sac ‘accompany’	1.08863	0.53742	2.026	0.04280	*
saj/sañj ‘hang’	0.75019	0.63812	1.176	0.23975	
sic ‘pour out’	0.87504	0.62572	1.398	0.16197	
sṛj ‘send forth’	1.32386	0.69645	1.901	0.05732	.
sphūrj ‘rumble’	2.61330	1.49274	1.751	0.08000	.
svaj/svañj ‘embrace’	0.77423	0.74916	1.033	0.30139	

In the Significance column, *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$, all statistically significant; . = $p < 0.1$, statistically non-significant, same for Table 2.2.

For suffixes, I manually merge some suffix types for the Bayesian regression model. For example, (-)F́G/FG(root)(-), (-)ĹG/LG(root)(-) and (-)ŹG/ZG(root)(-), their accent and stem types do not affect their overall tendency to have final palatal segments, so they can be merged as ROOT type.

Table 2.2: Bayesian logistic regression model for the suffixes

Suffix	Estimate	Standard error	*z* value	Prob(>|*t*|)	Significance
ROOT	3.44056	0.83615	4.115	$3.88e^{-5}$	***
(-)ŹG-*a*	-2.10557	1.49908	-1.405	0.16015	
(-)ZG-*a*	1.02727	0.49103	2.092	0.03643	*
ZG-*á*	0.57524	0.77594	0.741	0.45848	
-FG-*a*(-)	0.34381	0.34175	1.006	0.31440	
(-)F́G-*a*	-1.34032	0.59039	-2.270	0.02319	*
FG-*á*	-0.29876	0.44941	-0.665	0.50618	
ĹG-*a*	-0.00000	1.14360	-0.000	1.00000	
LG-*a*	-1.73754	1.53087	-1.135	0.25637	
-LG-*a*	1.46034	0.88087	1.658	0.09735	.
LG-*á*	-0.24569	0.70400	-0.349	0.72710	
-*ā*	2.29311	0.84125	2.726	0.00641	**
-*as*	1.45920	0.51634	2.826	0.00471	**
-*ana*	3.52733	0.64466	5.472	$4.46e^{-8}$	***
-*anā*	2.38644	1.49132	1.600	0.10955	
ZG-*ā́nā*	1.20165	1.64372	0.731	0.46474	
ZG-*iná*	1.20165	1.64372	0.731	0.46474	
FG-*anā́nas*	1.20165	1.64372	0.731	0.46474	
-*anīya*	4.17455	1.60227	2.605	0.00918	**
-*iṣṇu*	2.38644	1.49132	1.600	0.10955	
-FG-*ayiṣṇu*	1.20165	1.64372	0.731	0.46474	
-*ra*	-0.63836	0.52121	-1.225	0.22066	
-*ira*	1.73754	1.53087	1.135	0.25637	
ZG-*lá*	-1.20165	1.64372	-0.731	0.46474	
F́G-*ri*	-1.20165	1.64372	-0.731	0.46474	
-FG-*ara*	1.20165	1.64372	0.731	0.46474	
ZG-*ā́ra*	1.20165	1.64372	0.731	0.46474	
-*aka*	4.86931	1.67612	2.905	0.00367	**
-ZG-*īká*	1.20165	1.64372	0.731	0.46474	
ŹG-*ika*	1.20165	1.64372	0.731	0.46474	
-*uka*	0.49982	1.01501	0.492	0.62242	
-*ūka*	1.73754	1.53087	1.135	0.25637	
-*ma*	-1.28926	0.89605	-1.439	0.15020	
-*man*	-0.87504	0.62572	-1.398	0.16197	
-*aya*	1.08539	0.91844	1.182	0.23730	
ZG-*ayā́*	1.20165	1.64372	0.731	0.46474	
-*yā*	0.83291	0.95369	0.873	0.38247	
LG-*íyā*	1.20165	1.64372	0.731	0.46474	
FG-*atíya*	1.20165	1.64372	0.731	0.46474	
ZG-*ipyá*	1.20165	1.64372	0.731	0.46474	
ZG-*īpín*	1.20165	1.64372	0.731	0.46474	
-*ya*	1.26584	0.31846	3.975	$7.04e^{-5}$	***
-*íya*	-1.28926	0.89605	-1.439	0.15020	
-*u*	-0.36107	0.60672	-0.595	0.55176	

-īyas	1.46034	0.88087	1.658	0.09735	.
-i	2.26459	0.55556	4.076	$4.58e^{-5}$	***
-in	0.41351	0.32596	1.269	0.20459	
-ī	0.32816	0.81604	0.402	0.68758	
-is	2.61330	1.49274	1.751	0.08000	.
-iṣṭha	3.23760	1.52120	2.128	0.03331	*
-átha	2.10557	1.49908	1.405	0.16015	
-itṛ	2.38644	1.49132	1.600	0.10955	
-ayitṛ/ṛ́	3.64088	1.55224	2.346	0.01900	*
F́G/FG-*atra-*	1.73754	1.53087	1.135	0.25637	
FG-*átri*	1.20165	1.64372	0.731	0.46474	
ZG-*iti*	1.20165	1.64372	0.731	0.46474	
ŹG-*īti*	1.20165	1.64372	0.731	0.46474	
ZG-*īṣá*	1.20165	1.64372	0.731	0.46474	
FG-*vin*	1.73754	1.53087	1.135	0.25637	
-va	-2.38644	1.49132	-1.600	0.10955	
ZG-*ūnas*	1.20165	1.64372	0.731	0.46474	
F́G-*una*	1.20165	1.64372	0.731	0.46474	
-van	-1.85255	0.85624	-2.164	0.03050	*
-vaná	-1.73754	1.53087	-1.135	0.25637	
Des.Redup.-*váni*	-1.20165	1.64372	-0.731	0.46474	
FG-*vanú*	-1.20165	1.64372	-0.731	0.46474	
ŹG-*vas*	-1.20165	1.64372	-0.731	0.46474	
ZG-*íśvan*	1.20165	1.64372	0.731	0.46474	
FG-*ivā́ṃs*	-1.20165	1.64372	-0.731	0.46474	
-athu	1.73754	1.53087	1.135	0.25637	
-itavya	2.38644	1.49132	1.600	0.10955	
-ayitav(i)ya	3.23760	1.52120	2.128	0.03331	*
-ita	-0.00000	1.14360	-0.000	1.00000	
FG-*álā*	-1.20165	1.64372	-0.731	0.46474	
FG-*ū́ra*	1.20165	1.64372	0.731	0.46474	
(-)Des.Redup.-*iṣu*	2.10557	1.49908	1.405	0.16015	
(-)FG-*ati*	1.73754	1.53087	1.135	0.25637	
FG-*atá*	2.10557	1.49908	1.405	0.16015	
FG-*elima*	1.20165	1.64372	0.731	0.46474	
FG-*ná*	1.73754	1.53087	1.135	0.25637	
LG-*nā́*	1.20165	1.64372	0.731	0.46474	
-nya	1.73754	1.53087	1.135	0.25637	
Intens.Redup.-*á*	1.73754	1.53087	1.135	0.25637	
-enya	1.73754	1.53087	1.135	0.25637	
LG-*ayú*	1.20165	1.64372	0.731	0.46474	
-FG-*anu*	1.20165	1.64372	0.731	0.46474	
FG-*urá*	-1.20165	1.64372	-0.731	0.46474	
-yu	2.10557	1.49908	1.405	0.16015	
-iṣ(i)ya	1.73754	1.53087	1.135	0.25637	

LG-*āra*	1.20165	1.64372	0.731	0.46474
LG-*ālíya*	1.20165	1.64372	0.731	0.46474
-FG-*alya*	1.20165	1.64372	0.731	0.46474
F́G-*us*	1.20165	1.64372	0.731	0.46474
-ani/ī	1.73754	1.53087	1.135	0.25637
-an	2.10557	1.49908	1.405	0.16015
F́G-*nas*	-1.20165	1.64372	-0.731	0.46474
-ZG-*atnu*	1.20165	1.64372	0.731	0.46474
ŹG-*mant*	-1.20165	1.64372	-0.731	0.46474
ŹG-*ant*	1.20165	1.64372	0.731	0.46474
FG-*nú*	-1.20165	1.64372	-0.731	0.46474
F́G-*mya*	-1.73754	1.53087	-1.135	0.25637
FG-*át*	1.20165	1.64372	0.731	0.46474

3 The Bayesian logistic regression model with two predictors

Table 3: Bayesian logistic regression model for both the roots and the suffixes

Root/Suffix	**Estimate**	**Standard error**	***z* value**	**Prob(>|*t*|)**	**Significance**
(Intercept)	1.62478	0.40672	3.995	$6.00e^{-5}$	***
ac/añc ‘bend’	-0.89240	0.90045	-0.991	0.32165	
aj ‘drive’	2.30460	0.98901	2.330	0.01980	*
āñch? ‘tear’	0.07639	2.33200	0.033	0.97387	
añj ‘anoint’	-0.33485	0.83622	-0.400	0.68883	
arc/ṛc ‘shine, praise’	0.35417	0.83264	0.425	0.67058	
bhaj ‘divide, share’	-0.56180	0.68307	-0.822	0.41081	
bhañj ‘break’	-2.53876	1.09670	-2.315	0.02062	*
bhiṣaj ‘heal’	1.34368	1.65983	0.810	0.41821	
bhrāj ‘shine’	-0.06740	0.80321	-0.084	0.93312	
bhṛjj ‘roast’	0.13776	2.22205	0.062	0.95057	
bhuj[1] ‘bend’	0.48096	1.07514	0.447	0.65463	
bhuj[2] ‘enjoy’	-0.66892	0.71087	-0.941	0.34672	
*carc** ‘repeat’	0.79115	1.71852	0.460	0.64525	
dhraj/dhrāj ‘sweep’	1.55774	1.56561	0.995	0.31975	
ej/īj ‘stir’	0.72299	1.77039	0.408	0.68299	
garj ‘roar’	1.36907	1.55397	0.881	0.37831	
guñj ‘hum’	1.09768	1.61702	0.679	0.49725	
iṅg ‘stir’	-4.31725	1.45314	-2.971	0.00297	**
iṣ → ich ‘seek’	1.36208	1.67961	0.811	0.41739	
khañj ‘limp’	0.88673	1.70169	0.521	0.60230	
kuc/kuñc ‘shrink, curl’	1.51035	1.52176	0.993	0.32095	
*kūj** ‘hum’	0.64219	1.76718	0.363	0.71631	
lāñch ‘mark’	0.54552	1.82177	0.299	0.76460	
lajj ‘be ashamed’	0.09865	2.29657	0.043	0.96574	

loc ‘see, consider’	1.06669	1.61559	0.660	0.50909
luñc ‘tear’	-1.61864	1.31733	-1.229	0.21917
mañj? ‘purify’	0.88673	1.70169	0.521	0.60230
majj ‘sink’	0.68420	1.15818	0.591	0.55468
mlech ‘speak barbarously’	1.32634	1.66969	0.794	0.42698
mṛc ‘injure’	-0.56888	1.15993	-0.490	0.62382
mṛj ‘wipe’	-0.68290	0.84920	-0.804	0.42130
mruc/mluc ‘set’	0.12078	1.07886	0.112	0.91086
muc ‘release’	0.15253	0.72938	0.209	0.83435
mūrch ‘thicken’	-1.75925	1.39532	-1.261	0.20737
nij ‘wash’	-0.67091	0.94133	-0.713	0.47602
pac ‘cook’	-0.27109	0.77024	-0.352	0.72487
paj? ‘start’	2.16830	1.70255	1.274	0.20282
prach ‘ask’	1.04056	1.62530	0.640	0.52203
pṛc ‘mix’	-1.20668	1.36874	-0.882	0.37799
pūj ‘reverence’	0.62561	1.75412	0.357	0.72135
ṛ → ṛch ‘go, send’	0.09865	2.29657	0.043	0.96574
rac ‘produce’	1.13655	1.58834	0.716	0.47426
rāj ‘be kingly’	1.49551	1.55698	0.961	0.33679
rac/rañj ‘color’	-0.62161	0.82971	-0.749	0.45374
rañch ‘mark’	0.07639	2.33200	0.033	0.97387
ric ‘leave’	-0.67854	0.73684	-0.921	0.35711
ṛj ‘shine’	2.29795	1.66787	1.378	0.16827
ṛj/ṛñj/arj ‘direct, stretch, attain’	0.67521	0.97951	0.689	0.49061
ruc ‘shine’	0.19577	0.67487	0.290	0.77175
ruj ‘break’	-1.21507	1.01699	-1.195	0.23218
sac ‘accompany’	-0.11192	0.74710	-0.150	0.88092
saj/sañj ‘hang’	-0.77839	0.80646	-0.965	0.33445
sic ‘pour out’	-0.48880	0.87495	-0.559	0.57639
sphūrj ‘rumble’	0.81915	1.68664	0.486	0.62720
sṛj ‘send forth’	0.23557	0.89412	0.263	0.79219
svaj/svañj ‘embrace’	-0.55613	0.89107	-0.624	0.53255
tañc/tac ‘coagulate’	-1.94361	1.31083	-1.483	0.13815
tarj ‘threaten’	0.12151	2.24801	0.054	0.95689
tij ‘be sharp’	-0.60116	0.87414	-0.688	0.49163
tuc ‘impel, generate’	-1.55665	1.29579	-1.201	0.22963
tuj ‘urge, thrust’	-0.28685	0.93065	-0.308	0.75792
tyaj ‘forsake’	-0.12335	0.84211	-0.146	0.88355
ubj? ‘force’	-0.88067	1.18714	-0.742	0.45819
uc ‘be pleased’	-2.10252	1.18013	-1.782	0.07482
*uñch** ‘glean’	0.54580	1.83243	0.298	0.76581
*ujh** ‘forsake’	0.75648	1.74773	0.433	0.66513
vac ‘speak’	-0.64510	0.62626	-1.030	0.30297
vañc ‘move crookedly’	-1.40153	1.15454	-1.214	0.22478
vaj ‘be strong’	1.59603	1.05076	1.519	0.12878

vāñch ‘desire’	0.09865	2.29657	0.043	0.96574	
vic ‘sift’	-2.01763	0.99958	-2.018	0.04354	*
vij ‘tremble’	0.05019	1.06695	0.047	0.96248	
*vīj/vyaj** ‘fan’	0.13776	2.22205	0.062	0.95057	
vraj ‘proceed’	1.71215	1.51984	1.127	0.25994	
vraśc ‘cut up’	-0.84171	1.03573	-0.813	0.41641	
vṛj ‘twist’	0.66297	0.80680	0.822	0.41123	
*vyac/vic** ‘extend’	0.62807	1.76017	0.357	0.72123	
yāc ‘ask’	1.44877	1.53713	0.943	0.34593	
yam → *yach* ‘reach’	0.07639	2.33200	0.033	0.97387	
yaj ‘offer’	2.11249	0.96010	2.200	0.02779	*
yuj ‘join’	-1.81832	0.65479	-2.777	0.00549	**
śak ‘be able’	-2.14545	0.83161	-2.580	0.00988	**
*śiñj** ‘twang’	1.06492	1.65381	0.644	0.51963	
śuc ‘gleam’	-0.58560	0.65728	-0.891	0.37296	
śvañj ‘spread’	-1.62688	1.65784	-0.981	0.32643	
(-)F́G-*a*	-2.88816	0.77410	-3.731	0.00019	***
(-)ŹG-*a*	-2.76534	1.60906	-1.719	0.08569	.
(-)Des.Redup.-*iṣu*	0.65359	1.75958	0.371	0.71030	
(-)FG-*ati*	0.25919	2.06720	0.125	0.90022	
(-)ZG-*a*	0.00386	0.69400	0.006	0.99556	
F́G/FG-*atra*-	0.47016	1.87802	0.250	0.80232	
-FG-*a*(-)	-0.94560	0.52367	-1.806	0.07096	.
-FG-*alya*	0.71625	1.79158	0.400	0.68932	
-FG-*anu*	1.82531	1.77564	1.028	0.30396	
-FG-*ara*	1.52331	1.77384	0.859	0.39047	
-FG-*ayiṣṇu*	0.72400	1.76666	0.410	0.68194	
-LG-*a*	-0.96910	0.95263	-1.017	0.30902	
-ZG-*atnu*	1.00718	1.74953	0.576	0.56483	
-ZG-*īká*	0.10092	2.29433	0.044	0.96492	
F́G-*mya*	-2.87821	1.64703	-1.748	0.08055	.
F́G-*nas*	-1.82953	1.70588	-1.072	0.28350	
F́G-*ri*	-1.36110	1.76360	-0.772	0.44025	
F́G-*una*	0.10092	2.29433	0.044	0.96492	
F́G-*us*	0.11756	2.25982	0.052	0.95851	
ĹG-*a*	-0.69608	1.50898	-0.461	0.64459	
ŹG-*ant*	0.46364	1.89015	0.245	0.80623	
ŹG-*ika*	0.83597	1.77962	0.470	0.63854	
ŹG-*īti*	0.10092	2.29433	0.044	0.96492	
ŹG-*mant*	-2.56477	1.75932	-1.458	0.14489	
ŹG-*vas*	-0.94891	1.73053	-0.548	0.58346	
-*ā*	2.32414	1.53237	1.517	0.12934	
-*átha*	1.00870	1.63085	0.619	0.53624	
-*aka*	3.74775	1.59101	2.356	0.01849	*
-*an*	0.52706	1.84778	0.285	0.77546	

-*ana*	2.61897	0.76880	3.407	0.00066	***
-*anā*	3.54619	2.07583	1.708	0.08758	.
-*ani/ī*	0.86375	1.69880	0.508	0.61114	
-*anīya*	2.96821	1.51698	1.957	0.05039	.
-*as*	0.18540	0.64954	0.285	0.77531	
-*athu*	0.51819	1.88475	0.275	0.78336	
-*aya*	-0.06086	1.06458	-0.057	0.95441	
-*ayitav(i)ya*	2.23448	1.51520	1.475	0.14029	
-*ayitṛ/ṛ́*	2.43166	1.50591	1.615	0.10637	
Des.Redup.-*váni*	-1.89540	1.69418	-1.119	0.26324	
-*enya*	1.09989	1.62342	0.678	0.49808	
FG-*á*	-1.82969	0.62170	-2.943	0.00325	**
FG-*álā*	-2.37309	1.70078	-1.395	0.16293	
FG-*átri*	0.42127	1.92658	0.219	0.82691	
FG-*anā́nas*	0.42127	1.92658	0.219	0.82691	
FG-*át*	0.55726	1.84192	0.303	0.76224	
FG-*atá*	1.03591	1.63387	0.634	0.52607	
FG-*atíya*	0.61052	1.81889	0.336	0.73713	
FG-*elima*	0.61052	1.81889	0.336	0.73713	
FG-*ivā́ṃs*	-0.97987	1.77896	-0.551	0.58176	
FG-*ná*	0.33310	2.00555	0.166	0.86809	
FG-*nú*	-1.84898	1.68739	-1.096	0.27318	
FG-*ū́ra*	0.51980	1.84436	0.282	0.77807	
FG-*urá*	-0.78222	1.79718	-0.435	0.66338	
FG-*vanú*	-1.84898	1.68739	-1.096	0.27318	
FG-*vin*	0.19115	2.14223	0.089	0.92890	
-*i*	0.99964	0.68017	1.470	0.14164	
-*ī*	-0.34785	1.06012	-0.328	0.74282	
-*in*	-1.03945	0.48688	-2.135	0.03277	*
Intens.Redup.-*á*	0.76359	1.73080	0.441	0.65908	
-*ira*	0.50171	1.85452	0.271	0.78675	
-*is*	1.44140	1.53006	0.942	0.34616	
-*iṣ(i)ya*	0.93971	1.66092	0.566	0.57154	
-*iṣṇu*	0.85575	1.66219	0.515	0.60667	
-*iṣṭha*	2.19492	1.53028	1.434	0.15148	
-*itavya*	1.1965	1.58095	0.757	0.44915	
-*itṛ*	1.62944	1.57113	1.037	0.29968	
-*íya*	-2.20814	1.03956	-2.124	0.03366	*
-*īyas*	0.01889	1.03224	0.018	0.98540	
LG-*a*	-2.79910	1.64853	-1.698	0.08952	.
LG-*á*	-1.56810	0.87266	-1.797	0.07235	.
LG-*ālíya*	0.76533	1.77150	0.432	0.66572	
LG-*āra*	0.76533	1.77150	0.432	0.66572	
LG-*ayú*	0.71528	1.77236	0.404	0.68653	
LG-*íyā*	0.11756	2.25982	0.052	0.95851	

LG-*nā́*	0.19939	2.15644	0.092	0.92633	
-ma	-2.73359	1.19734	-2.283	0.02243	*
-man	-1.99644	0.87588	-2.279	0.02265	*
-nya	0.38627	1.95764	0.197	0.84358	
-ra	-2.92116	0.80556	-3.626	0.00029	***
ROOT	2.11503	0.88644	2.386	0.01703	***
-u	-1.85273	0.77208	-2.400	0.01641	*
-uka	-0.84293	1.22760	-0.687	0.49230	
-ūka	0.39774	1.93981	0.205	0.83754	
-va	-3.53627	1.68081	-2.104	0.03539	*
-van	-3.25976	1.07676	-3.027	0.00247	**
-vaná	-2.61805	1.60747	-1.629	0.10338	
-ya	0.14992	0.48223	0.311	0.75589	
-yā	-0.64444	1.34745	-0.478	0.63246	
-yu	0.70669	1.72998	0.408	0.68291	
ZG-*á*	0.09067	0.91475	0.099	0.92104	
ZG-*ā́nā*	1.00718	1.74953	0.576	0.56483	
ZG-*ā́ra*	0.26491	2.09565	0.126	0.89941	
ZG-*ayā́*	0.45398	1.90926	0.238	0.81205	
ZG-*íśvan*	0.34306	1.99292	0.172	0.86333	
ZG-*iná*	0.34522	1.98446	0.174	0.86189	
ZG-*īpín*	0.34306	1.99292	0.172	0.86333	
ZG-*ipyá*	0.34306	1.99292	0.172	0.86333	
ZG-*īṣá*	0.34306	1.99292	0.172	0.86333	
ZG-*iti*	0.32927	2.05250	0.160	0.87255	
ZG-*lá*	-1.89540	1.69418	-1.119	0.26324	
ZG-*ūnas*	0.34306	1.99292	0.172	0.86333	

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Reference Abbreviations

EWA	Mayrhofer. 1992–200
LIV[2]	Rix et al. 2001
NIL	Wodtko et al. 2008

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