SOM - Read and data plotting from the manuscript Paixao et al. 2021 - JASr

Paixão et al.2021 - JARs

2021-03-03 09:33:26

Brief description of the script

This R markdown document reads, summarizes and plots data for the manuscript *Paixão et al. 2021 Using Mechanical experiments to study Ground Stone Tool use: exploring the formation of percussive and grinding wear traces on Limestone tools. Journal of Archaeological Science: Reports*

The document contains:

1. Manuscript tables
2. Manuscript figures (data analysis)
3. Supplementary material, including extra tables and figures (data analysis)

This R project and respective scripts follow the procedures described by Marwick et al. 2017.

To compile this markdown document do not delete or move files from their original folders. Please note that most of the tables and figures in this file do not match the numbering in the original manuscript.

For any questions, comments and inputs, please contact:

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Load data into R project

Imported files are in: '../analysis/raw_data'

Figures are saved in: '../analysis/plots'

Tables are saved in: '../analysis/derived_data'

Load libraries

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.0 --

## v ggplot2 3.3.3     v purrr   0.3.4
## v tibble  3.0.6     v dplyr   1.0.4
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.1
```

```
## -- Conflicts ---------------------------------------- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(utils)
library(knitr)
library(janitor)
```

```
##
## Attaching package: 'janitor'
```

```
## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test
```

```
library(kableExtra)
```

```
##
## Attaching package: 'kableExtra'
```

```
## The following object is masked from 'package:dplyr':
##
##     group_rows
```

```
library(GGally)
```

```
## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2
```

```
library(doBy)
```

```
##
## Attaching package: 'doBy'
```

```
## The following object is masked from 'package:dplyr':
##
##     order_by
```

```
library(ggpubr)
library(ggfortify)
library(tools)
```

Import datasets

```
gisdata <- read_csv("../raw_data/gisdata.csv")
```

```
##
## -- Column specification --------------------------------------------------------
## cols(
##   sample = col_character(),
##   cycle = col_character(),
##   parameter = col_character(),
##   motion = col_character(),
##   material = col_character(),
##   id = col_double(),
##   elev_min = col_double(),
##   elev_max = col_double(),
##   nparts = col_double(),
##   npoints = col_double(),
##   perimeter = col_double(),
##   area = col_double()
## )
```

```
confocaldata <- read.csv("../raw_data/confocaldata.csv", na.strings = "*****", encoding = "UTF-8")

data_file <- list.files("../raw_data/", pattern = "\\.csv$", full.names = TRUE)
md5_in <- md5sum(data_file)
info_in <- data.frame(file = basename(names(md5_in)), checksum = md5_in, row.names = NULL)
```

In this study two datasets are used:

1) **gisdata.csv**: dataset for the QGIS analysis

```
str(gisdata)
```

```
## spec_tbl_df [355 x 12] (S3: spec_tbl_df/tbl_df/tbl/data.frame)
##  $ sample   : chr [1:355] "id2-5" "id2-5" "id3-3" "id3-3" ...
##  $ cycle    : chr [1:355] "before" "before" "before" "before" ...
##  $ parameter: chr [1:355] "tri" "tri" "tri" "tri" ...
##  $ motion   : chr [1:355] "Impact" "Impact" "Impact" "Impact" ...
##  $ material : chr [1:355] "Flint" "Flint" "Flint" "Flint" ...
##  $ id       : num [1:355] 0 1 0 1 2 3 4 0 1 0 ...
##  $ elev_min : num [1:355] 0 0.01 0 0.01 0.02 0.03 0.04 0 0.01 0 ...
##  $ elev_max : num [1:355] 0.01 0.02 0.01 0.02 0.03 0.04 0.05 0.01 0.02 0.01 ...
##  $ nparts   : num [1:355] 1007 1010 131 165 47 ...
##  $ npoints  : num [1:355] 67487 59648 14961 16143 3142 ...
##  $ perimeter: num [1:355] 485.2 446 160.6 177.5 32.8 ...
##  $ area     : num [1:355] 204.49 17.48 83.65 38.12 1.83 ...
##  - attr(*, "spec")=
##   .. cols(
##   ..   sample = col_character(),
##   ..   cycle = col_character(),
##   ..   parameter = col_character(),
##   ..   motion = col_character(),
##   ..   material = col_character(),
##   ..   id = col_double(),
##   ..   elev_min = col_double(),
##   ..   elev_max = col_double(),
```

```
##   ..   nparts = col_double(),
##   ..   npoints = col_double(),
##   ..   perimeter = col_double(),
##   ..   area = col_double()
##   .. )
```

2) **confocaldata.csv**: dataset for the Confocal microscopy surface texture analysis analysis

```
str(confocaldata)
```

```
## 'data.frame':    25 obs. of  54 variables:
##  $ Name                              : chr  "Lime2-5_LSM_50x075_suf1_Topo > Leveled (LS-plane) > Fo
##  $ Created.on                        : chr  "6/24/2020 12:03:05 PM" "6/24/2020 12:21:59 PM" "6/24/2
##  $ sample                            : chr  "id2-5" "id2-5" "id2-5" "id3-3" ...
##  $ motion                            : chr  "impact" "impact" "impact" "impact" ...
##  $ workedmaterial                    : chr  "flint" "flint" "flint" "flint" ...
##  $ Studiable.type                    : chr  "Surface" "Surface" "Surface" "Surface" ...
##  $ Axis.name...X                     : chr  "X" "X" "X" "X" ...
##  $ Axis.length...X                   : num  255 255 255 255 255 ...
##  $ Axis.size...X                     : int  3000 3000 3000 1024 1024 3000 3000 1024 3000 3000 ...
##  $ Axis.spacing...X                  : num  85.2 85.2 85.2 249.6 249.6 ...
##  $ Axis.name...Y                     : chr  "Y" "Y" "Y" "Y" ...
##  $ Axis.length...Y                   : num  255 255 255 255 255 ...
##  $ Axis.size...Y                     : int  3000 3000 3000 1024 1024 3000 3000 1024 3000 3000 ...
##  $ Axis.spacing...Y                  : num  85.2 85.2 85.2 249.6 249.6 ...
##  $ Axis.name...Z                     : chr  "Z" "Z" "Z" "Z" ...
##  $ Layer.type...Z                    : chr  "Topography" "Topography" "Topography" "Topography" ...
##  $ Axis.length...Z                   : num  8.3 30.6 14.9 48.6 23 ...
##  $ Axis.size...Z                     : int  128164 333950 130813 193492 260079 181249 180484 428496
##  $ Axis.spacing...Z                  : num  0.0647 0.0916 0.1139 0.2511 0.0884 ...
##  $ NM.points.ratio...Z               : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ Sq                                : num  0.836 4.619 2.321 5.348 3.491 ...
##  $ Ssk                               : num  0.997 0.107 0.142 -0.491 0.201 ...
##  $ Sku                               : num  8.63 4.48 3.11 5.97 3.46 ...
##  $ Sp                                : num  4.8 15.02 7.46 23 11.88 ...
##  $ Sv                                : num  3.49 15.58 7.45 25.58 11.11 ...
##  $ Sz                                : num  8.3 30.6 14.9 48.6 23 ...
##  $ Sa                                : num  0.572 3.244 1.819 3.887 2.699 ...
##  $ Smr                               : num  0.464 0.497 0.448 0.18 0.354 ...
##  $ Smc                               : num  0.775 5.691 2.944 5.799 4.436 ...
##  $ Sxp                               : num  1.53 10.61 4.3 11.65 6.74 ...
##  $ Sal                               : num  13.5 18.9 20.1 18.7 22.9 ...
##  $ Str                               : num  0.371 0.416 0.592 0.468 0.803 ...
##  $ Std                               : num  149 65 150 51 124 ...
##  $ Sdq                               : num  0.328 1.153 0.688 1.126 0.897 ...
##  $ Sdr                               : num  4.36 20.02 16.47 31.23 24.6 ...
##  $ Vm                                : num  0.0866 0.3378 0.1331 0.3133 0.2114 ...
##  $ Vv                                : num  0.861 6.029 3.078 6.113 4.648 ...
##  $ Vmp                               : num  0.0866 0.3378 0.1331 0.3133 0.2114 ...
##  $ Vmc                               : num  0.528 3.111 2.097 3.932 3.146 ...
##  $ Vvc                               : num  0.769 5.335 2.824 5.33 4.303 ...
##  $ Vvv                               : num  0.0923 0.694 0.2534 0.7826 0.3444 ...
##  $ Maximum.depth.of.furrows          : num  4.56 20.63 7.65 25.68 13.88 ...
```

```
##  $ Mean.depth.of.furrows              : num  0.962 4.63 2.49 5.112 3.932 ...
##  $ Mean.density.of.furrows            : num  4523 3830 4509 2286 2201 ...
##  $ First.direction                    : num  1.50e+02 6.36e+01 2.66e-03 9.00e+01 9.00e+01 ...
##  $ Second.direction                   : num  180 45 154 45 135 ...
##  $ Third.direction                    : num  141.3 56.2 63.5 51.2 123.7 ...
##  $ Isotropy                           : num  23.5 26.2 77.8 33.1 73.8 ...
##  $ Lengthscale.anisotropy.Sfrax.epLsar: num  NA NA NA 0.000493 0.001218 ...
##  $ Lengthscale.anisotropy.NewEplsar   : num  NA NA NA 0.0177 0.0172 ...
##  $ Fractal.complexity.Asfc            : num  8.66 23.18 30.55 37.79 44.11 ...
##  $ Scale.of.max.complexity.Smfc       : num  1.71e+06 1.81e+08 2.71e+06 1.17e+01 1.52e+01 ...
##  $ HAsfc9                             : num  0.449 2.496 0.388 0.544 0.254 ...
##  $ HAsfc81                            : num  0.659 3.446 0.481 0.701 0.487 ...
```

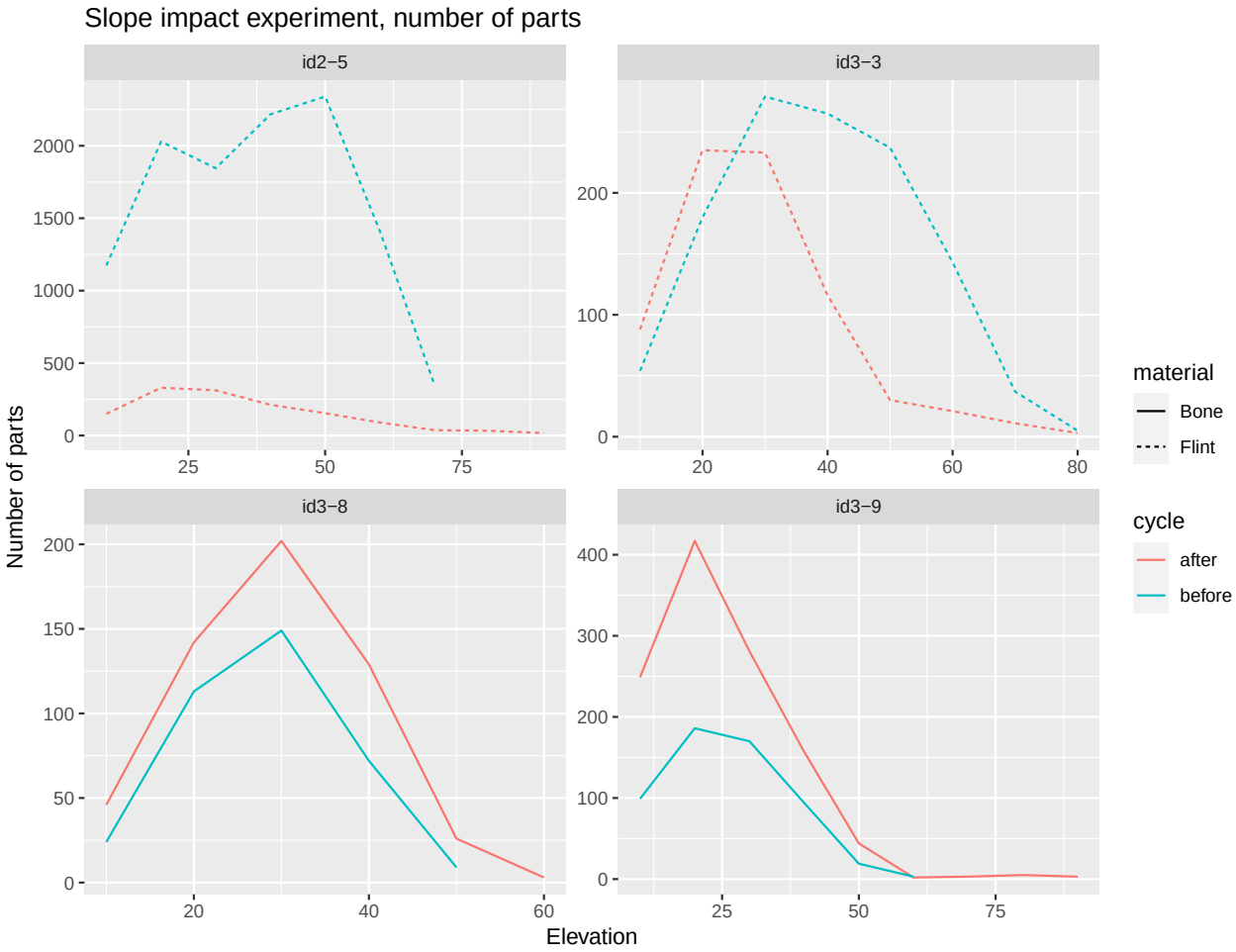
GIS analysis, Terrain analysis for Slope and TRI based on the 3D surface point clouds

Slope

```
# Compute proportions for perimeter and area grouped by sample and GIS parameter

slope <- filter(gisdata, parameter == "slope")
slopebefore <- filter(slope, cycle == "before")
slopeafter <-  filter(slope, cycle == "after")

# before experimental cycles (i.e. natural surfaces)

id2.5before <- filter(slopebefore, sample == "id2-5")
id3.3before <- filter(slopebefore, sample == "id3-3")
id3.8before <- filter(slopebefore, sample == "id3-8")
id3.9before <- filter(slopebefore, sample == "id3-9")
id6.1before <- filter(slopebefore, sample == "id6-1")
id6.3before <- filter(slopebefore, sample == "id6-3")
id6.6before <- filter(slopebefore, sample == "id6-6")
id6.7before <- filter(slopebefore, sample == "id6-7")

id2.5before <- id2.5before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3before <- id3.3before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8before <- id3.8before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9before <- id3.9before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.1before <- id6.1before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)
```

```r
id6.3before <- id6.3before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6before <- id6.6before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.7before <- id6.7before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

# after experimental cycles

id2.5after <- filter(slopeafter, sample == "id2-5")
id3.3after <- filter(slopeafter, sample == "id3-3")
id3.8after <- filter(slopeafter, sample == "id3-8")
id3.9after <- filter(slopeafter, sample == "id3-9")
id6.1after <- filter(slopeafter, sample == "id6-1")
id6.3after <- filter(slopeafter, sample == "id6-3")
id6.6after <- filter(slopeafter, sample == "id6-6")
id6.7after <- filter(slopeafter, sample == "id6-7")

id2.5after <- id2.5after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3after <- id3.3after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8after <- id3.8after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9after <- id3.9after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)
```

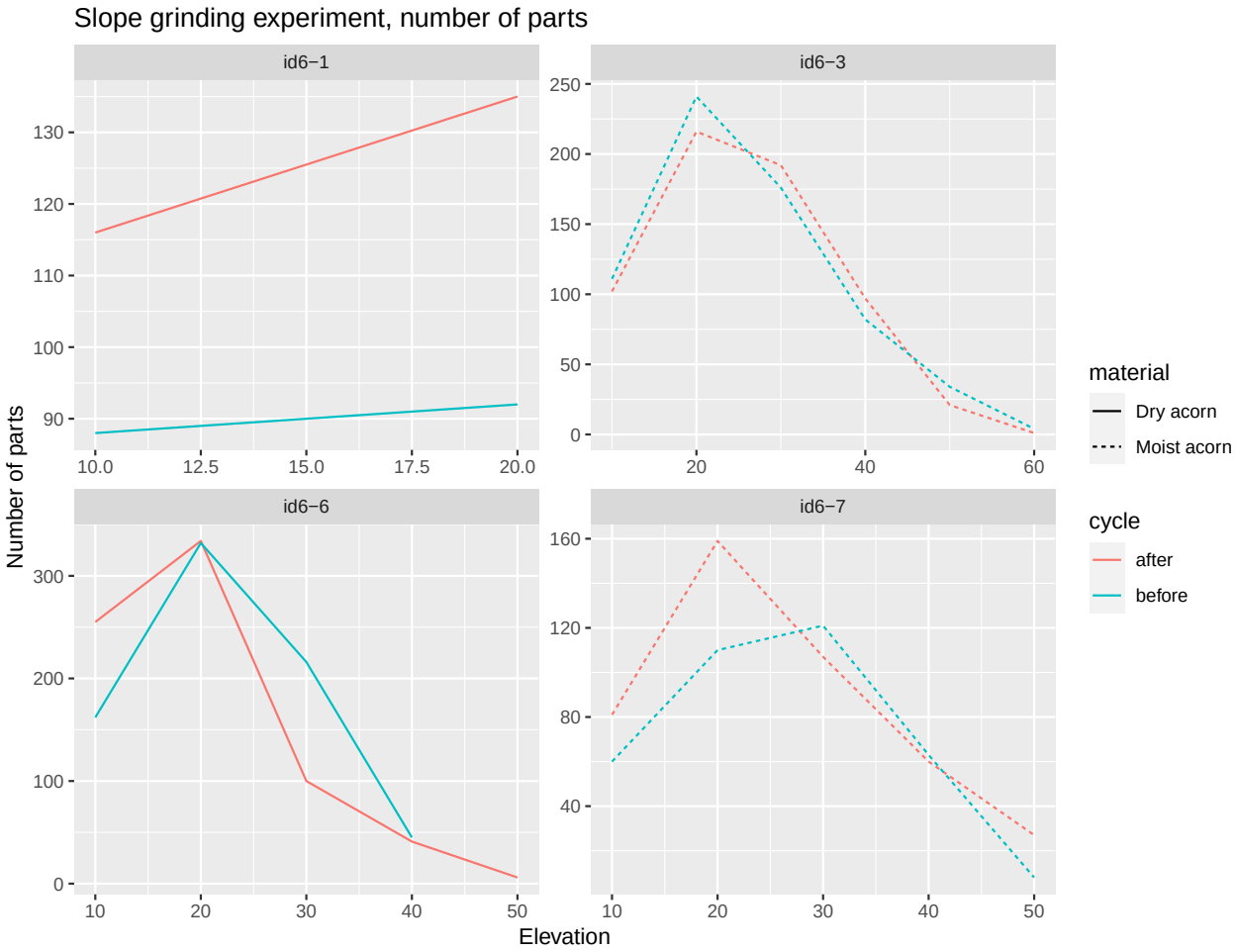
```r
id6.1after <- id6.1after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.3after <- id6.3after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6after <- id6.6after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.7after <- id6.7after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)


newslope <- do.call("rbind", list(id2.5before, id3.3before, id3.8before, id3.9before, id6.1before, id6.3

# save outputs

write_csv(newslope,"../derived_data/newslope.csv")

# Plot data

# Number of parts

impactdf <- filter(newslope, motion == "Impact")
grinding <- filter(newslope, motion == "Grinding")

slopepartsexp_impac <- ggplot(impactdf, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope impact experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

slopepartsexp_impac
```




```
ggsave("../plots/slopepartsexp_impac.png")
```

```
## Saving 8.5 x 6.5 in image
```

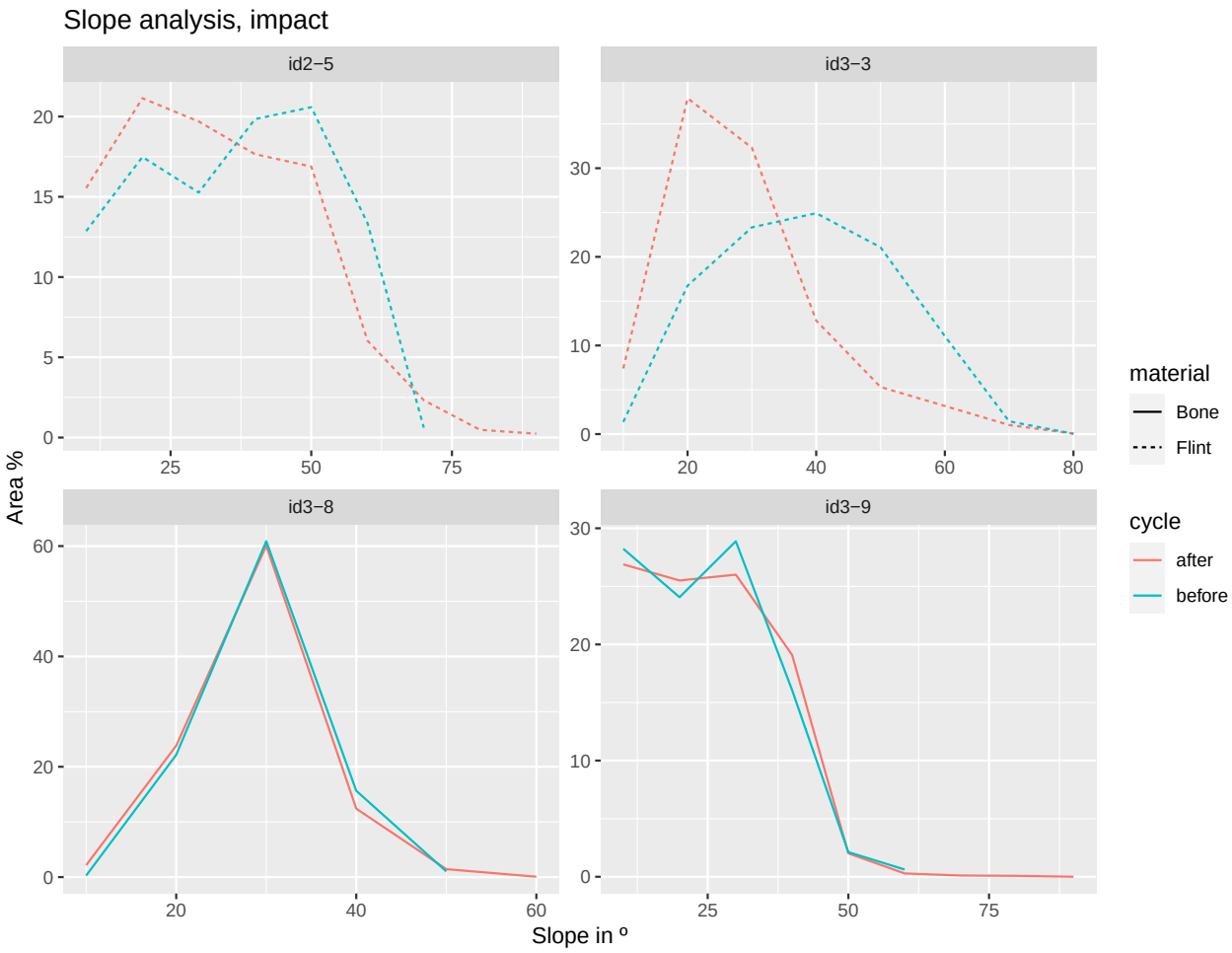
```
slopepartsexp_grind <- ggplot(grinding, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope grinding experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

slopepartsexp_grind
```




```
ggsave("../plots/slopepartsexp_grind.png")
```

```
## Saving 8.5 x 6.5 in image
```

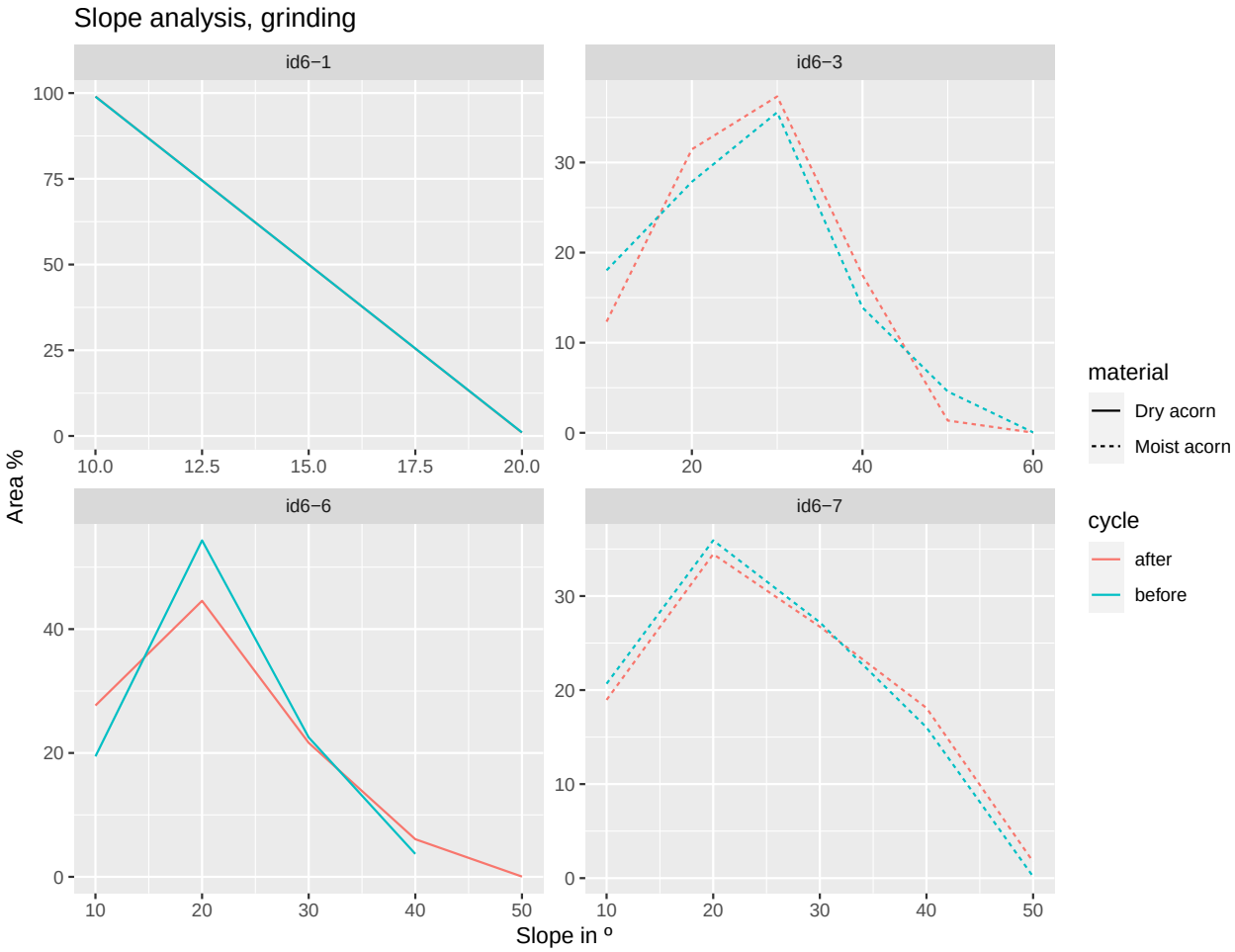
```
# Area %

impactdf <- filter(newslope, motion == "Impact")
grinding <- filter(newslope, motion == "Grinding")


areaimpact <- ggplot(impactdf, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope analysis, impact") +
  ylab("Area %") +
  xlab("Slope in º")

areaimpact
```




```
ggsave("../plots/slopeareaimpact.png")
```

```
## Saving 8.5 x 6.5 in image
```

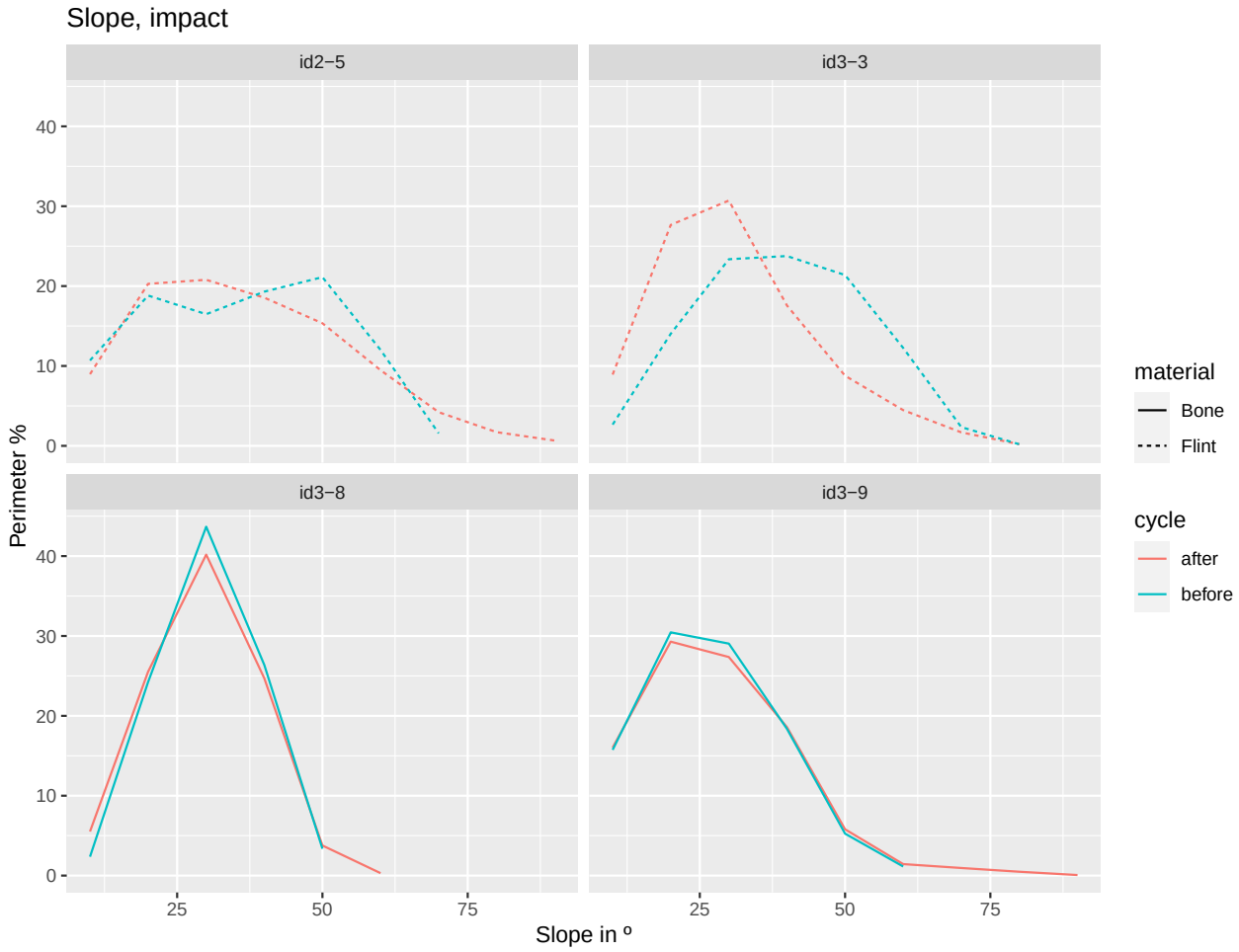
```
areagrinding <- ggplot(grinding, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope analysis, grinding") +
  ylab("Area %") +
  xlab("Slope in º")

areagrinding
```




```
ggsave("../plots/slopeareagrinding.png")
```

```
## Saving 8.5 x 6.5 in image
```

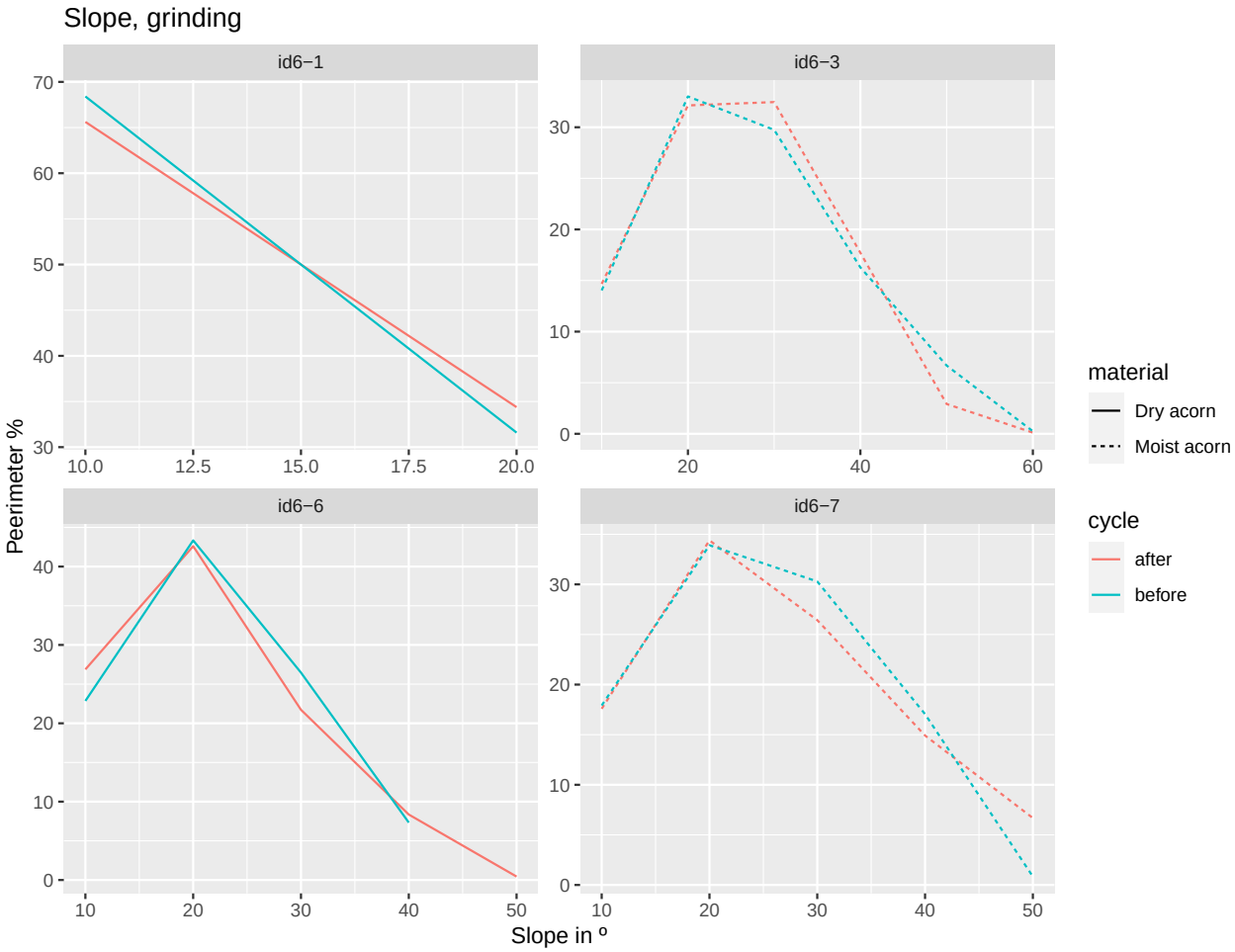
```
# Perimeter %

perimimpact <- ggplot(impactdf, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample) +
  ggtitle("Slope, impact") +
  ylab("Perimeter %") +
  xlab("Slope in º")

perimimpact
```




```
ggsave("../plots/slopeperimimpact.png")
```

```
## Saving 8.5 x 6.5 in image
```

```
perimgrinding <- ggplot(grinding, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope, grinding") +
  ylab("Peerimeter %") +
  xlab("Slope in º")

perimgrinding
```




```
ggsave("../plots/slopeperimgrinding.png")
```

```
## Saving 8.5 x 6.5 in image
```

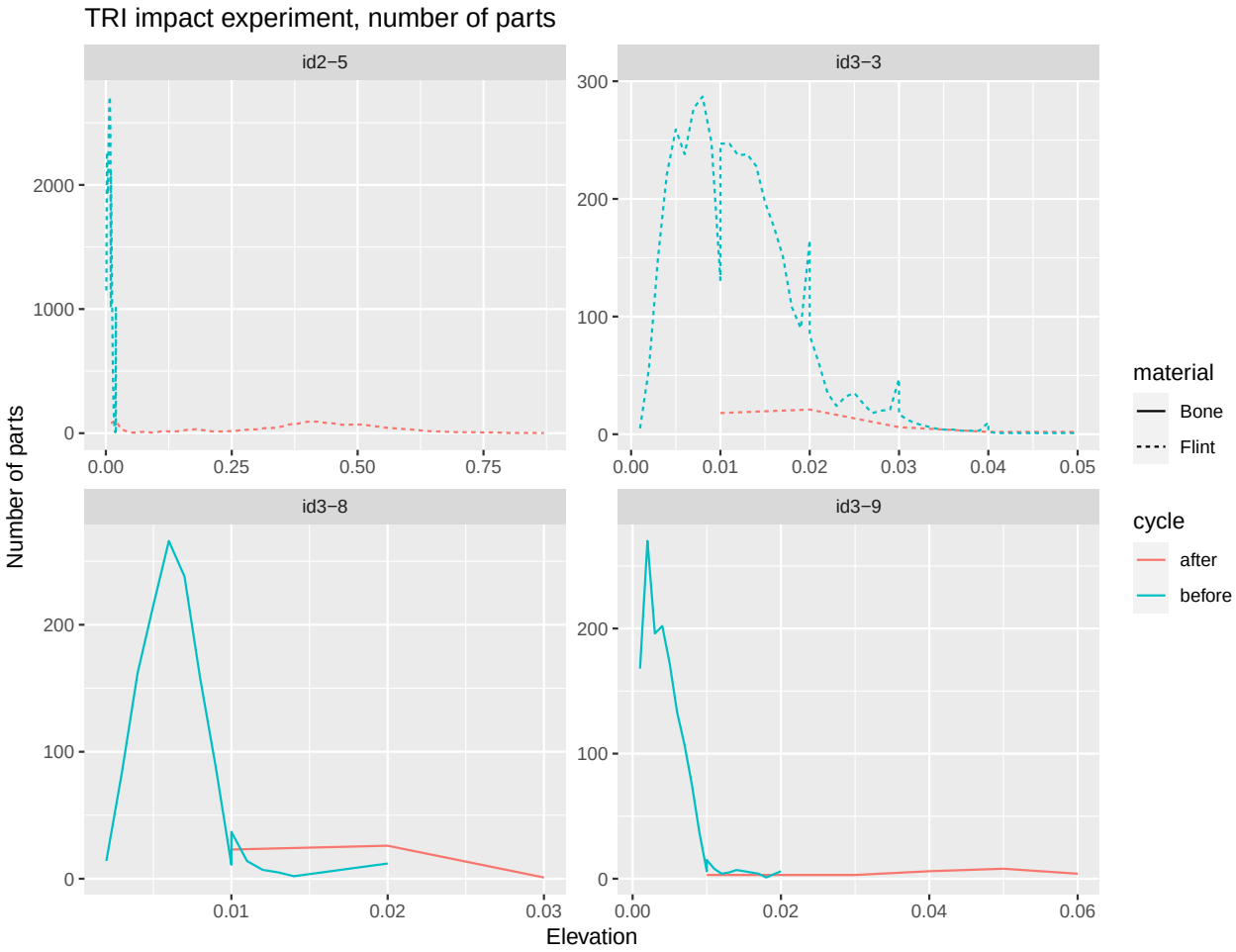
TRI (Terrain roughness index)

```
tri <- filter(gisdata, parameter == "tri")
tribefore <- filter(tri, cycle == "before")
triafter <- filter(tri, cycle =="after")


# before experimental cycles (i.e. natural surfaces)

id2.5before <- filter(tribefore, sample == "id2-5")
id3.3before <- filter(tribefore, sample == "id3-3")
id3.8before <- filter(tribefore, sample == "id3-8")
id3.9before <- filter(tribefore, sample == "id3-9")
id6.1before <- filter(tribefore, sample == "id6-1")
id6.3before <- filter(tribefore, sample == "id6-3")
id6.6before <- filter(tribefore, sample == "id6-6")
```

```r
id6.7before <- filter(tribefore, sample == "id6-7")

id2.5before <- id2.5before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3before <- id3.3before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8before <- id3.8before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9before <- id3.9before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.1before <- id6.1before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.3before <- id6.3before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6before <- id6.6before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.7before <- id6.7before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)


# after experimental cycles
```

```
id2.5after <- filter(triafter, sample == "id2-5")
id3.3after <- filter(triafter, sample == "id3-3")
id3.8after <- filter(triafter, sample == "id3-8")
id3.9after <- filter(triafter, sample == "id3-9")
id6.1after <- filter(triafter, sample == "id6-1")
id6.3after <- filter(triafter, sample == "id6-3")
id6.6after <- filter(triafter, sample == "id6-6")
id6.7after <- filter(triafter, sample == "id6-7")

id2.5after <- id2.5after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3after <- id3.3after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8after <- id3.8after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9after <- id3.9after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.1after <- id6.1after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.3after <- id6.3after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6after <- id6.6after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.7after <- id6.7after %>%
  group_by(sample) %>%
```

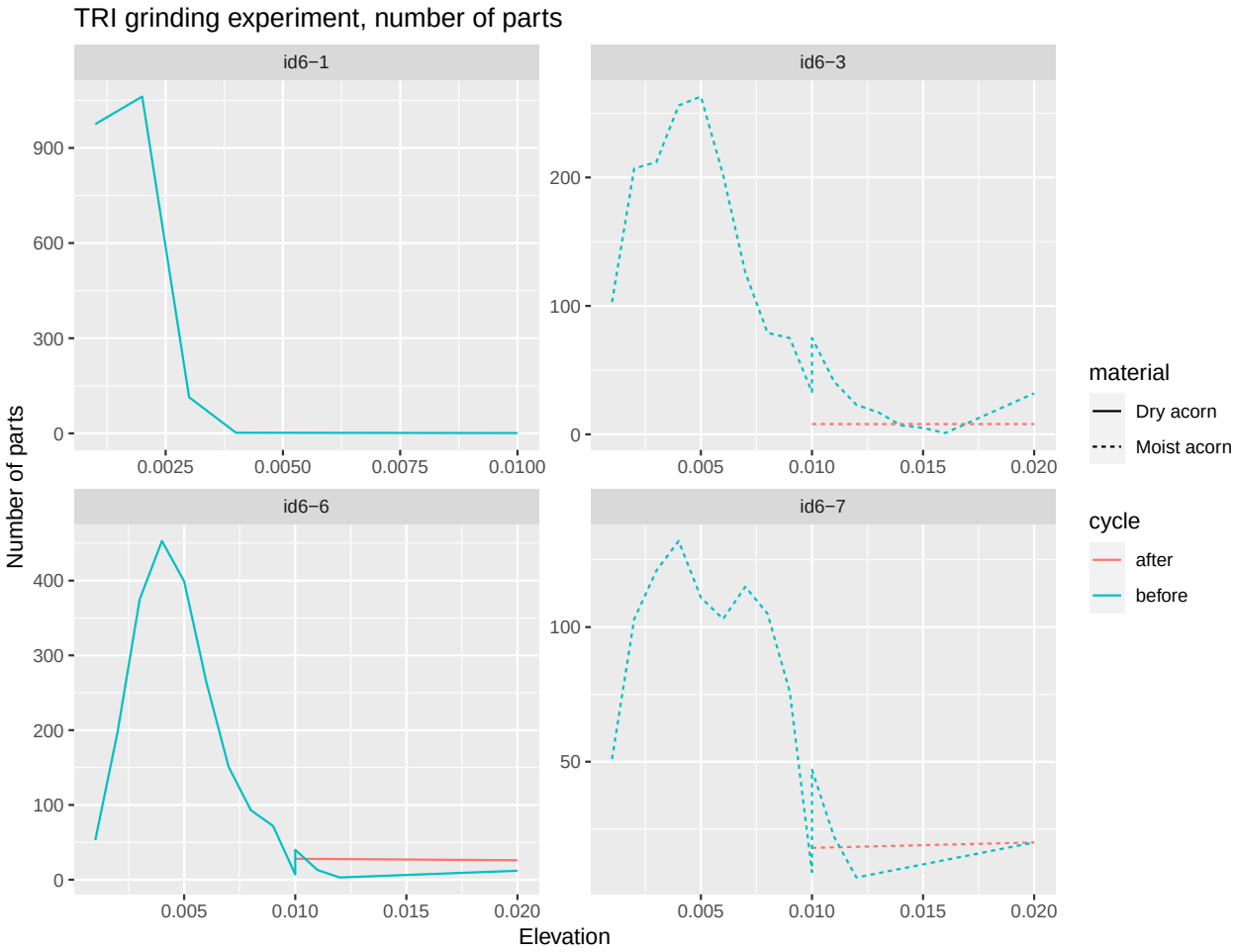
```
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)


newtri <- do.call("rbind", list(id2.5before, id3.3before, id3.8before, id3.9before, id6.1before, id6.3b

# save outputs

write_csv(newtri,"../derived_data/newtri.csv")

# Plot data

# Number of parts

# Motion
impactdf <- filter(newtri, motion == "Impact")
grinding <- filter(newtri, motion == "Grinding")

imapact_parts <- ggplot(impactdf, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI impact experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

imapact_parts
```




```
ggsave("../plots/tripartsexp_impac.png")
```

```
## Saving 8.5 x 6.5 in image
```

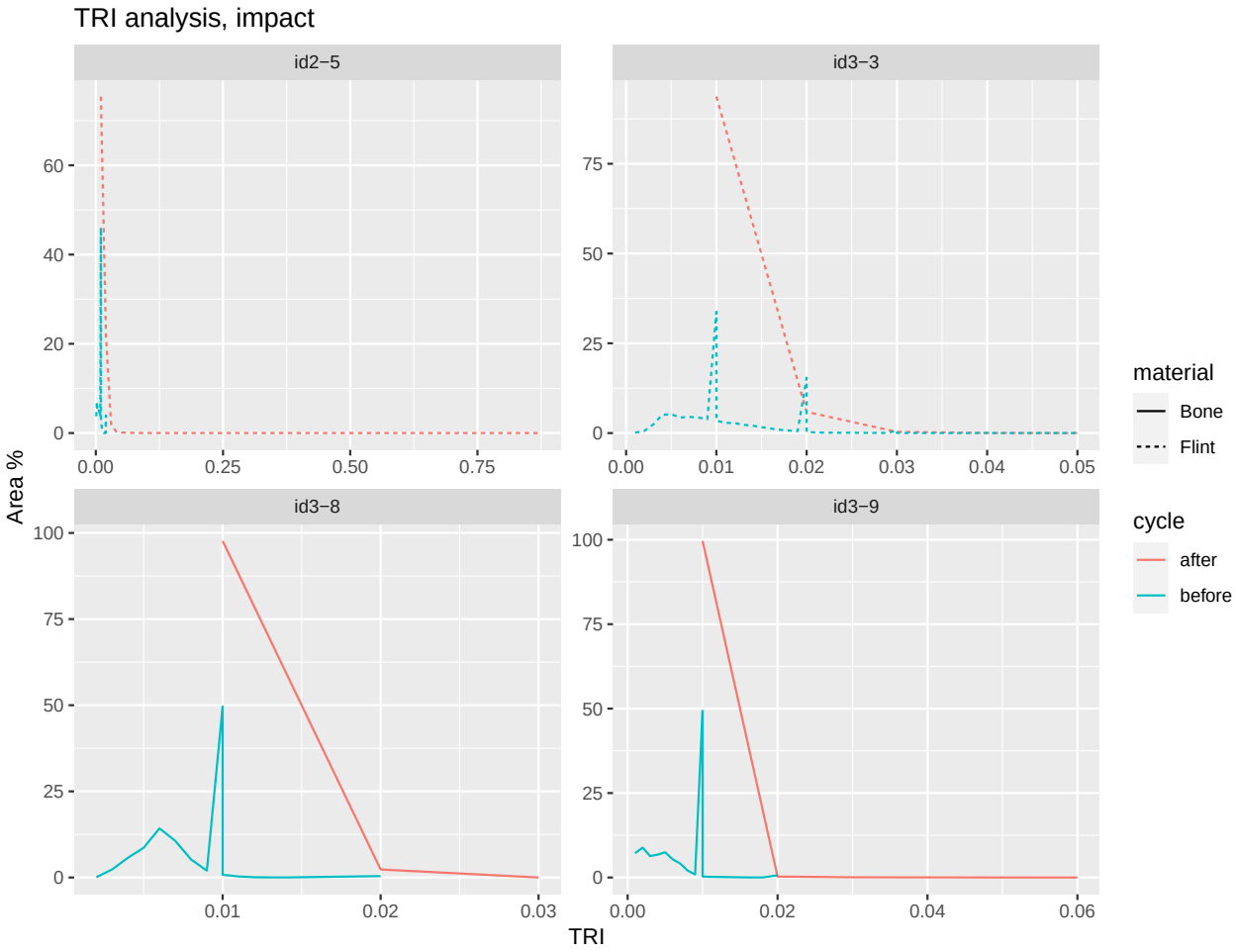
```
grinding_parts <- ggplot(grinding, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI grinding experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

grinding_parts
```




```
ggsave("../plots/tripartsexp_grind.png")
```

```
## Saving 8.5 x 6.5 in image
```

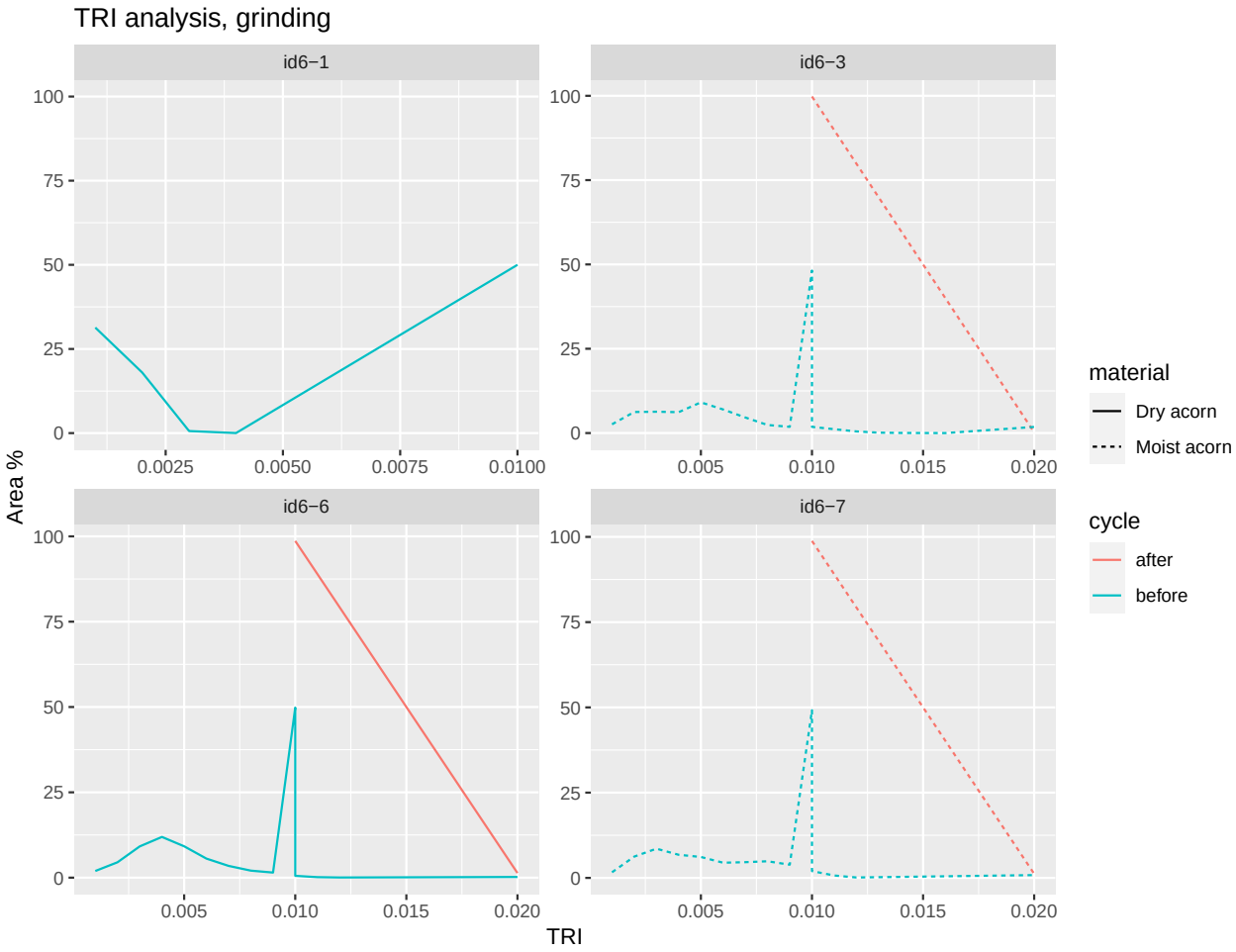
```
# Area %

areaimpact <- ggplot(impactdf, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI analysis, impact") +
  ylab("Area %") +
  xlab("TRI")

areaimpact
```




```
ggsave("../plots/triareaimpact.png")
```

```
## Saving 8.5 x 6.5 in image
```

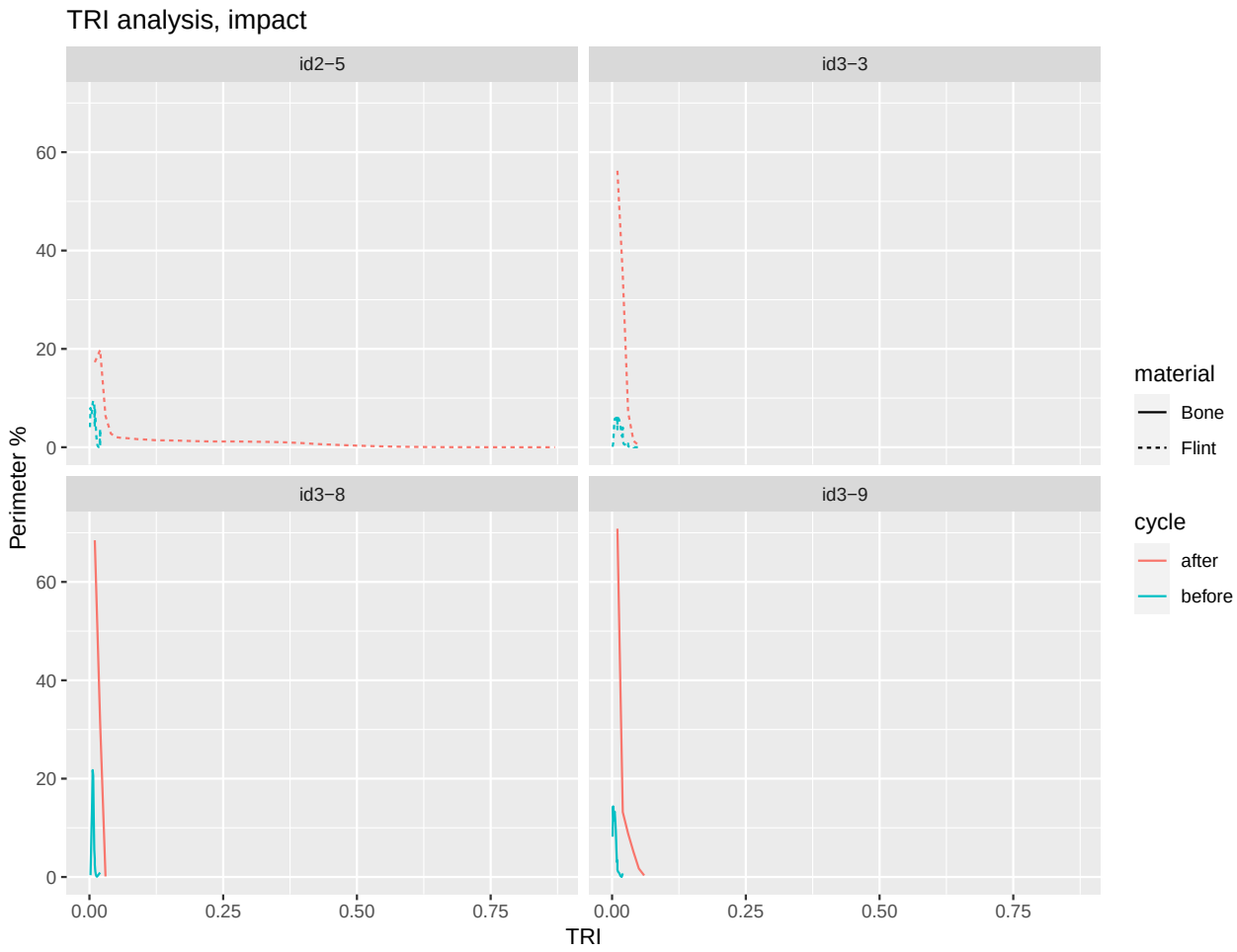
```
areagrinding <- ggplot(grinding, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI analysis, grinding") +
  ylab("Area %") +
  xlab("TRI")

areagrinding
```




```
ggsave("../plots/triareagrinding.png")
```

```
## Saving 8.5 x 6.5 in image
```

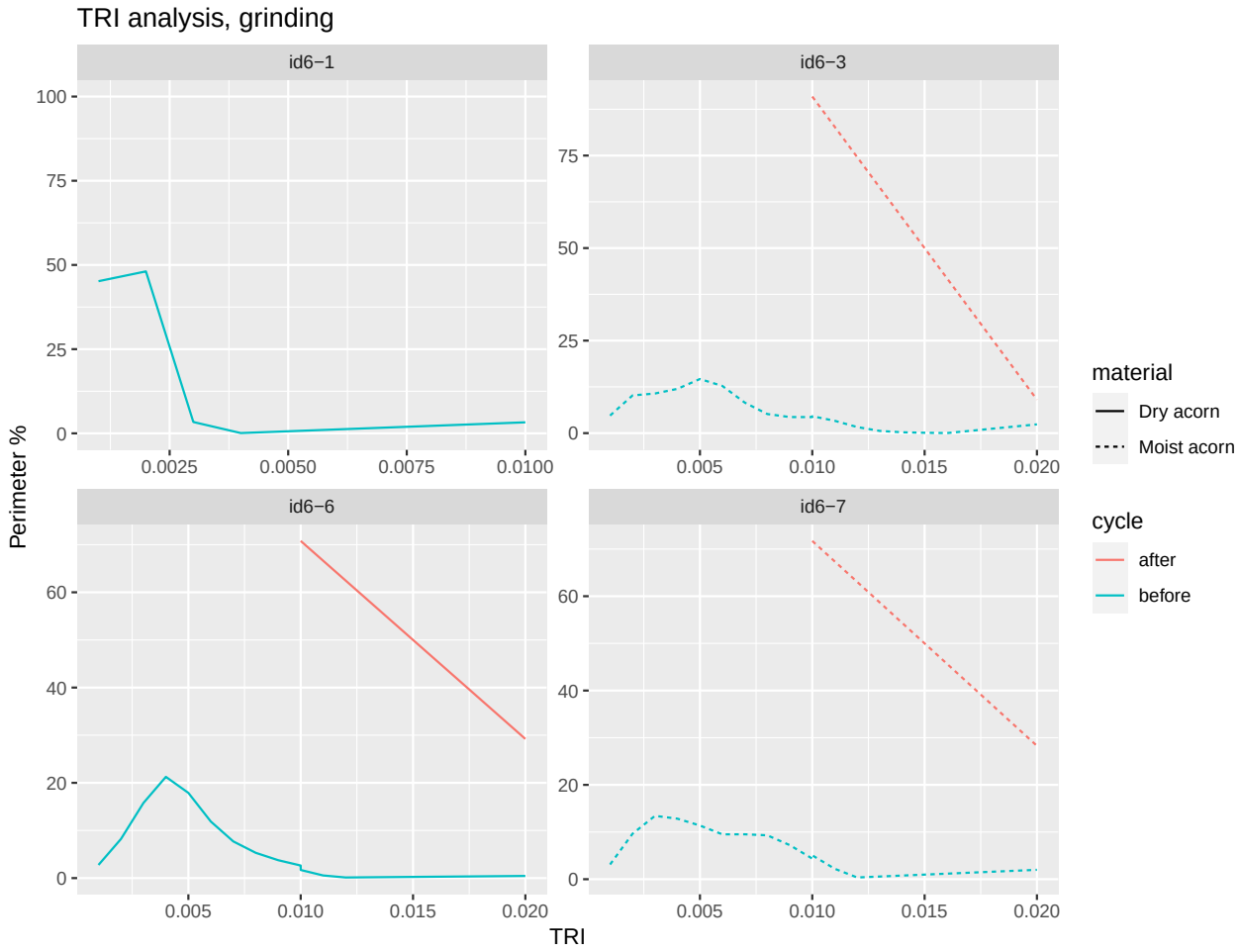
```
# Perimeter %

perimimpact <- ggplot(impactdf, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample) +
  ggtitle("TRI analysis, impact") +
  ylab("Perimeter %") +
  xlab("TRI")

perimimpact
```




```
ggsave("../plots/triperimimpact.png")
```

```
## Saving 8.5 x 6.5 in image
```

```
perimgrinding <- ggplot(grinding, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI analysis, grinding") +
  ylab("Perimeter %") +
  xlab("TRI")

perimgrinding
```




```
ggsave("../plots/triperimgrinding.png")
```

```
## Saving 8.5 x 6.5 in image
```

Confocal micro surface texture data

Import and summarize data

```
# compute descriptive statistics

nminmaxmeanmedsd <- function(x){
    y <- x[!is.na(x)]
    n_test <- length(y)
    min_test <- min(y)
    max_test <- max(y)
    mean_test <- mean(y)
    med_test <- median(y)
    sd_test <- sd(y)
    out <- c(n_test, min_test, max_test, mean_test, med_test, sd_test)
    names(out) <- c("n", "min", "max", "mean", "median", "sd")
```

```
    return(out)
}

num.var <- 21:length(confocaldata)

confostatsexp <- summaryBy(.~sample + motion + workedmaterial, data=confocaldata[c("sample", "motion","
```

```
## Warning in min(y): no non-missing arguments to min; returning Inf

## Warning in max(y): no non-missing arguments to max; returning -Inf

## Warning in min(y): no non-missing arguments to min; returning Inf

## Warning in max(y): no non-missing arguments to max; returning -Inf

## Warning in min(y): no non-missing arguments to min; returning Inf

## Warning in max(y): no non-missing arguments to max; returning -Inf

## Warning in min(y): no non-missing arguments to min; returning Inf

## Warning in max(y): no non-missing arguments to max; returning -Inf
```

```
write_csv(confostatsexp, "../derived_data/confostats.csv")
```

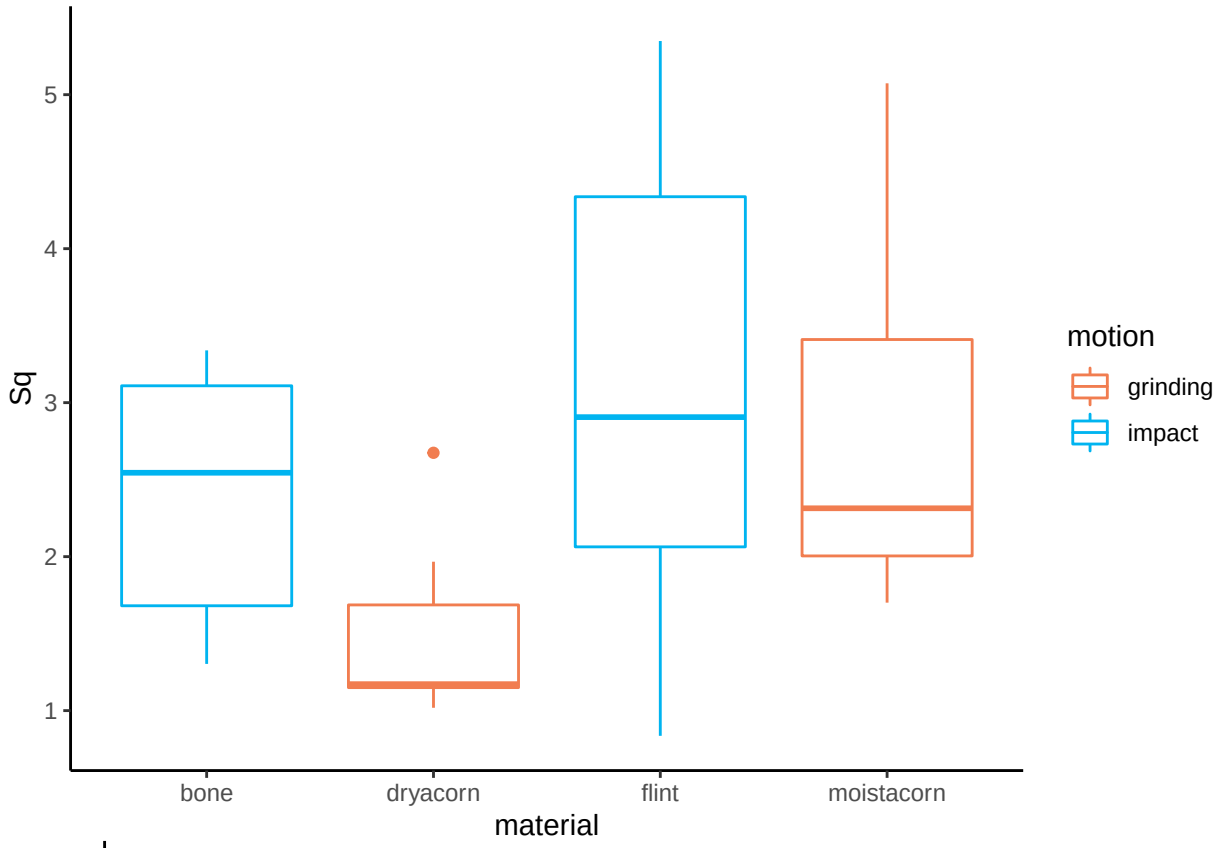
Plot all paramaters

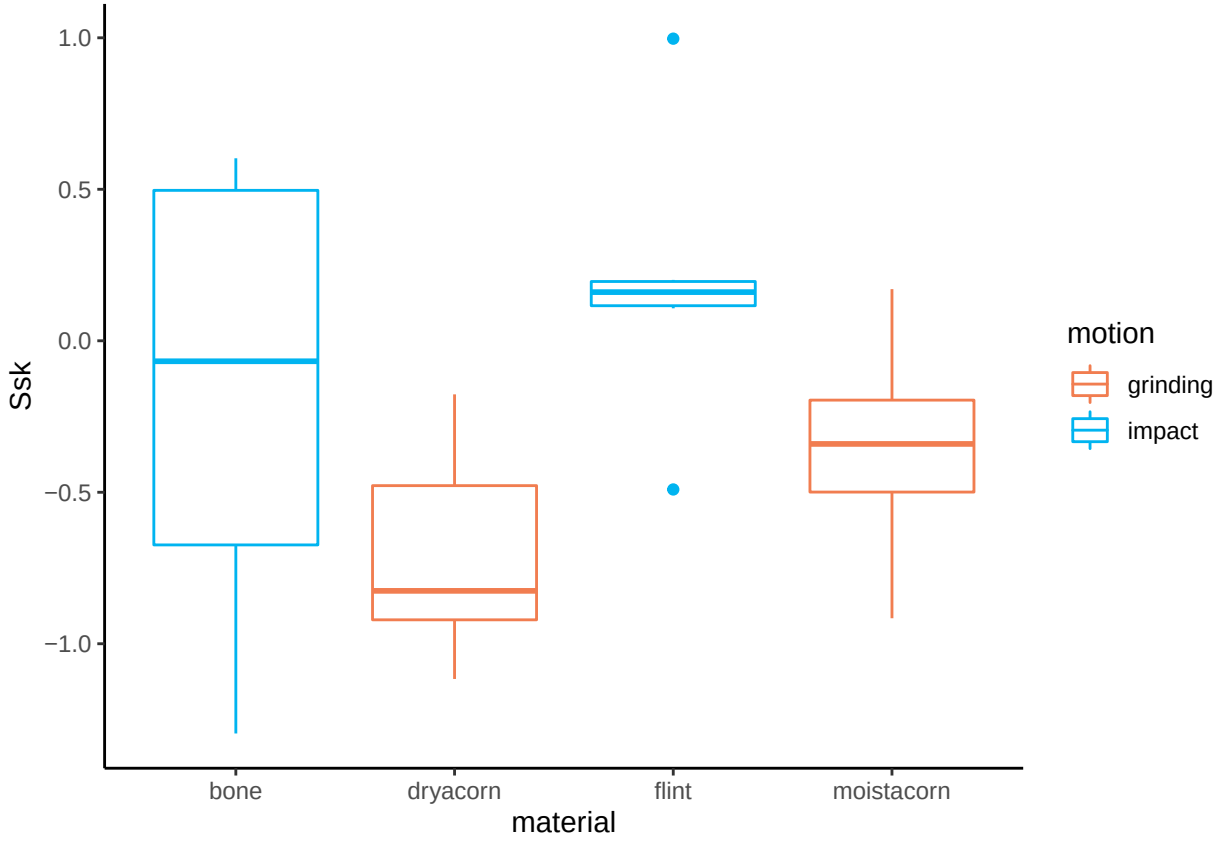
```
# Loop for plotting all surface texture parameters

for (i in num.var) cat("[",i,"] ", names(confocaldata)[i], "\n", sep = "")
```

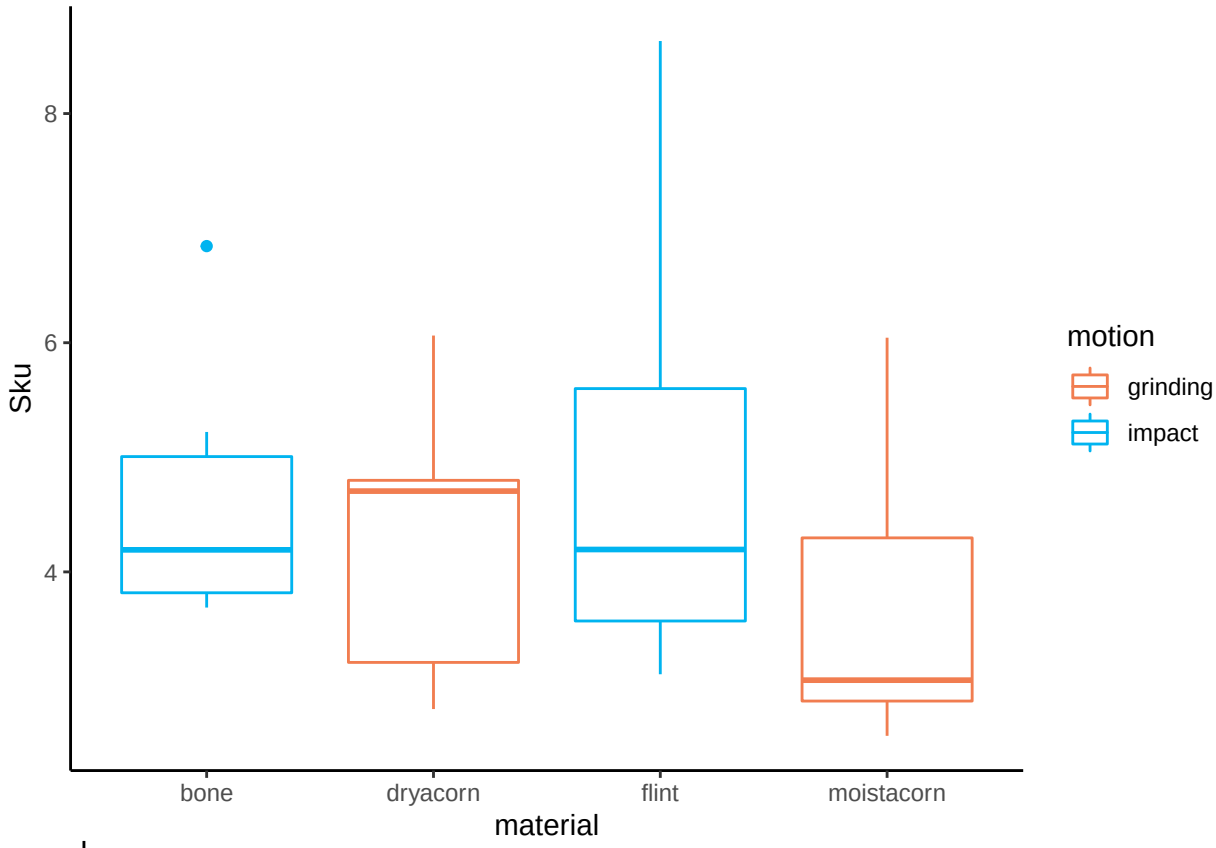
```
## [21] Sq
## [22] Ssk
## [23] Sku
## [24] Sp
## [25] Sv
## [26] Sz
## [27] Sa
## [28] Smr
## [29] Smc
## [30] Sxp
## [31] Sal
## [32] Str
## [33] Std
## [34] Sdq
## [35] Sdr
## [36] Vm
## [37] Vv
```

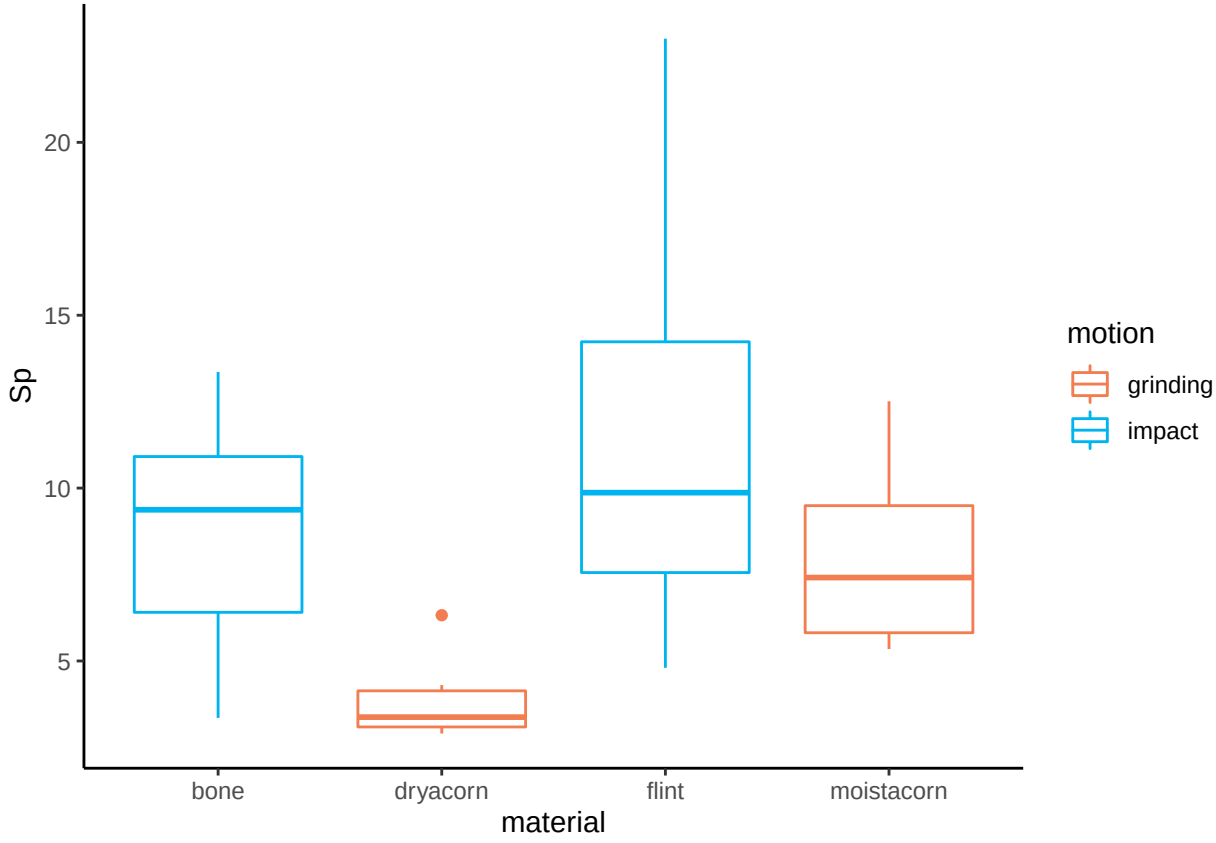
```
## [38] Vmp
## [39] Vmc
## [40] Vvc
## [41] Vvv
## [42] Maximum.depth.of.furrows
## [43] Mean.depth.of.furrows
## [44] Mean.density.of.furrows
## [45] First.direction
## [46] Second.direction
## [47] Third.direction
## [48] Isotropy
## [49] Lengthscale.anisotropy.Sfrax.epLsar
## [50] Lengthscale.anisotropy.NewEplsar
## [51] Fractal.complexity.Asfc
## [52] Scale.of.max.complexity.Smfc
## [53] HAsfc9
## [54] HAsfc81
```

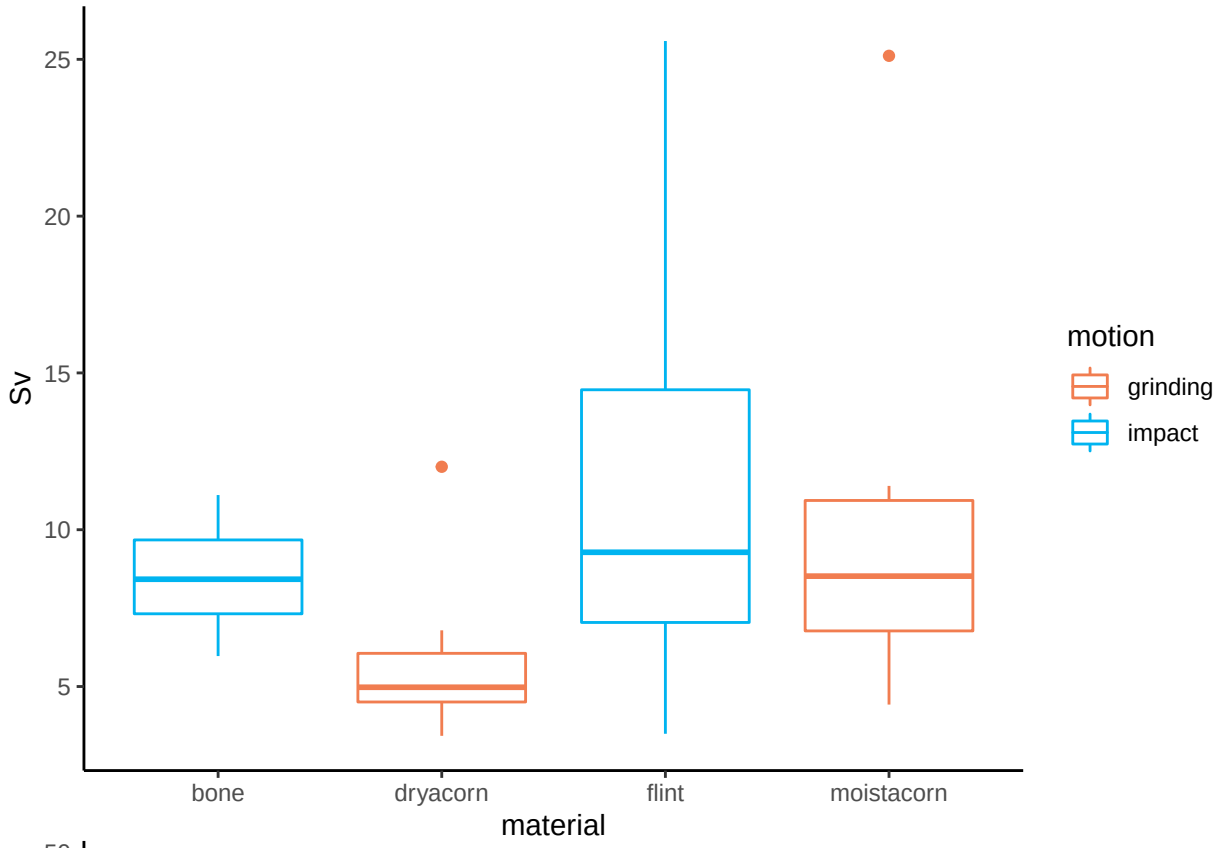
```r
for (i in num.var) {
  p <- ggplot(data = confocaldata, aes_string(x = "workedmaterial", y = names(confocaldata)[i],
                                              colour = "motion")) +
         geom_boxplot() +
         # geom_line(aes(group = motion)) +
         theme_classic() +
         labs(colour = "motion") +
         # facet_wrap(~ sample) +
         labs(x = "material", y = gsub("\\.", " ", names(confocaldata)[i])) +
         scale_colour_hue(h = c(25,225), limits = levels(confocaldata[["motion"]]))
  print(p)

  # saves the plots
  file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_plot_",
                     names(confocaldata)[i], ".pdf")
    ggsave(filename = file_out, plot = p, path = "../plots", device = "pdf", width = 26,
           height = 21, units = "cm" )
}
```

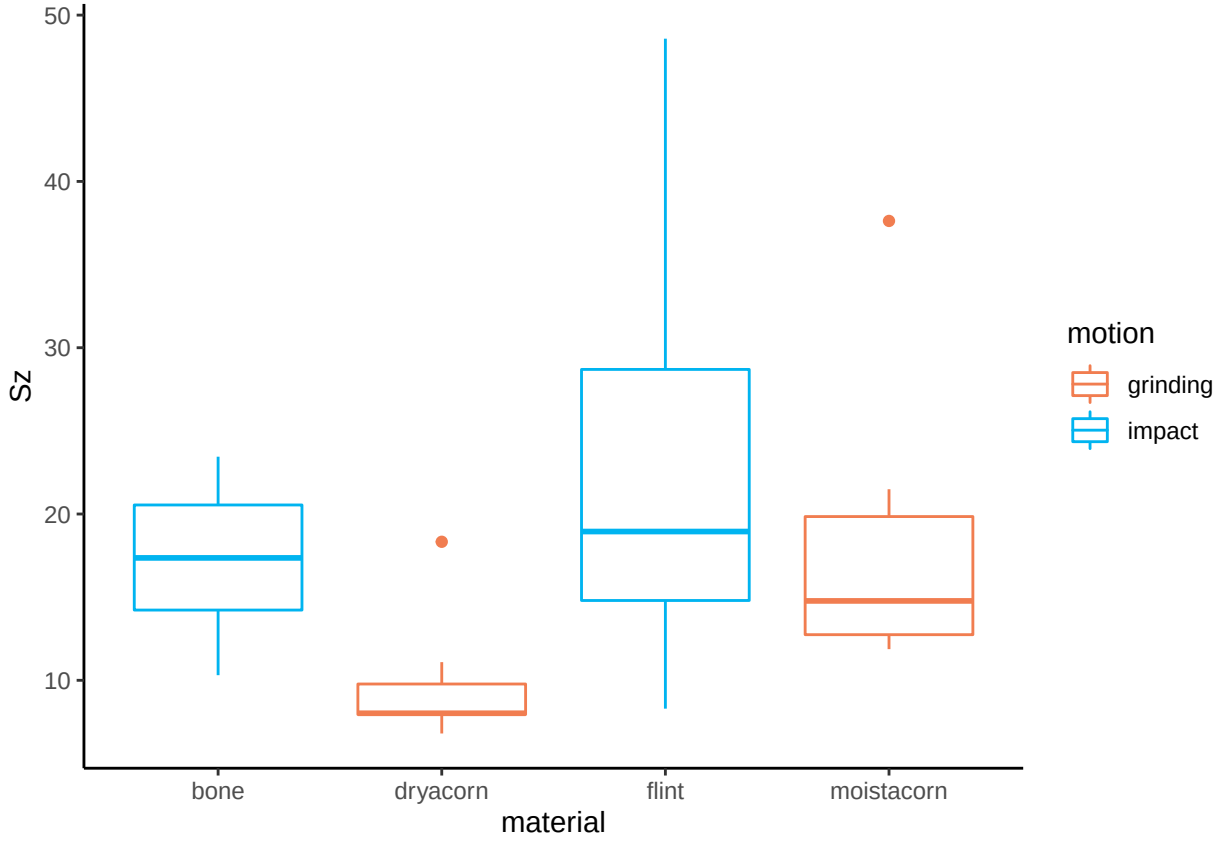

Sq
5
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

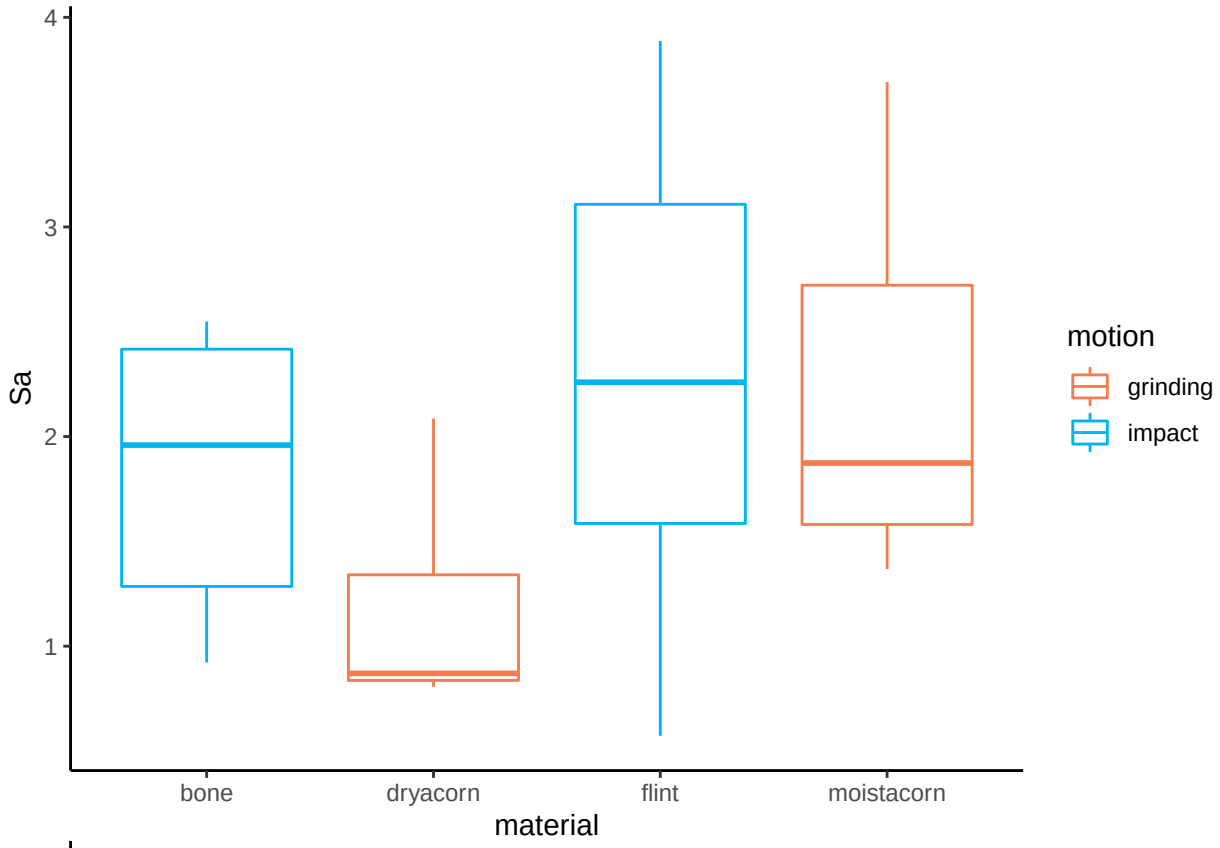

Ssk
1.0
0.5
0.0
−0.5
−1.0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

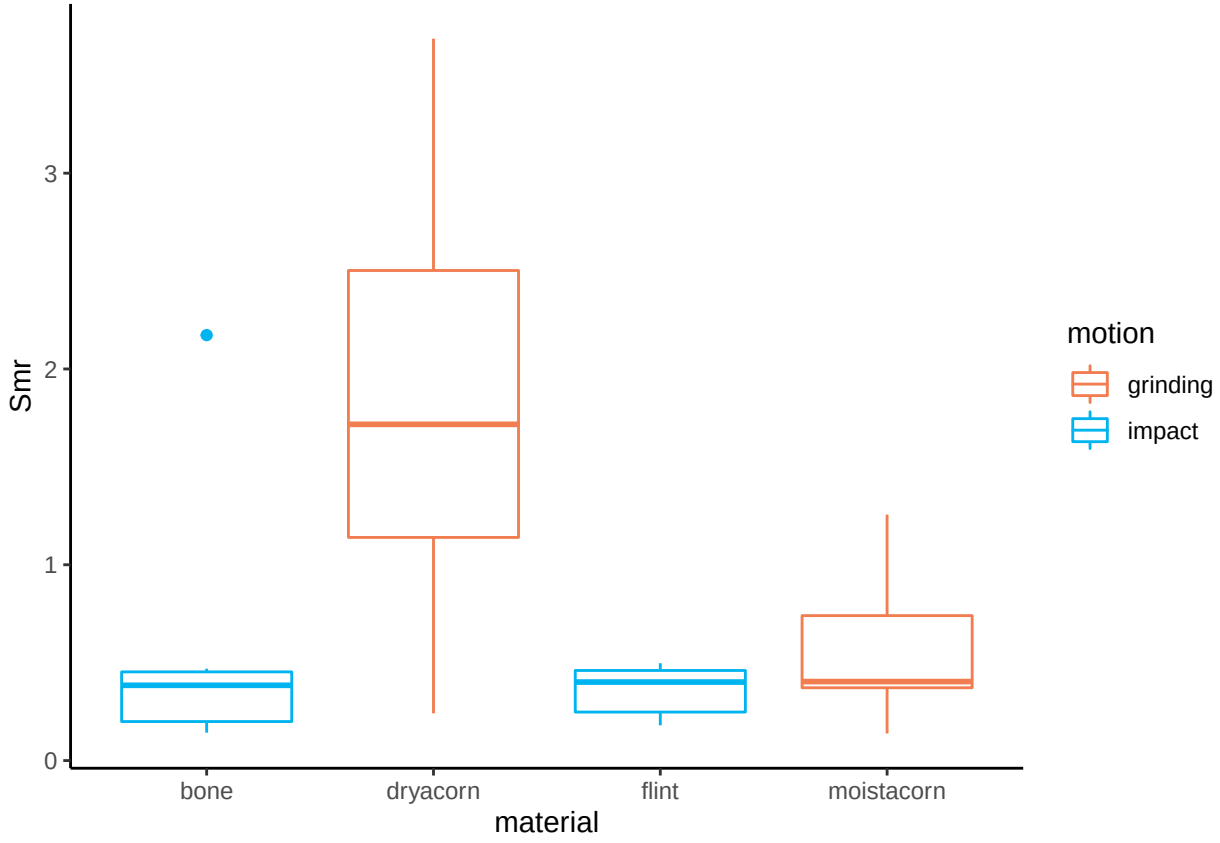

Sku
8
6
4
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

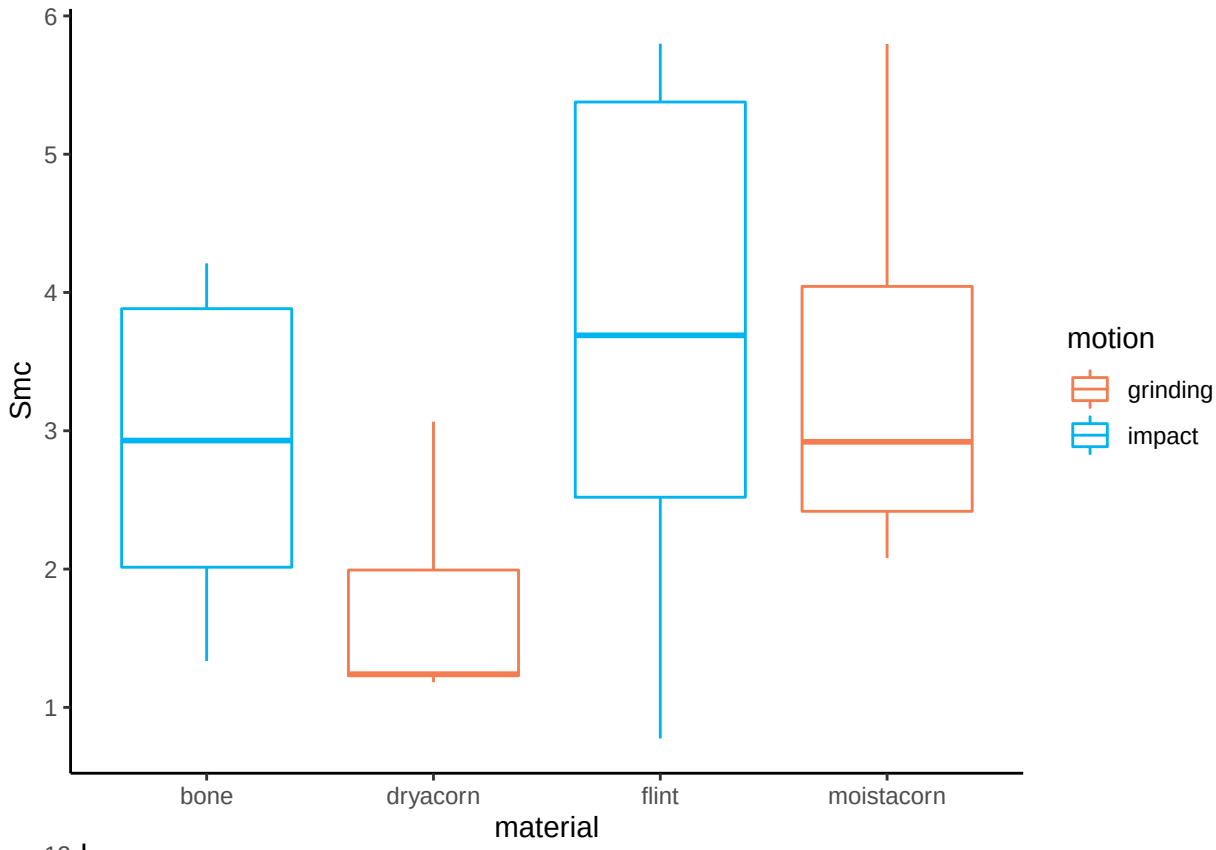

Sp
20
15
10
5
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

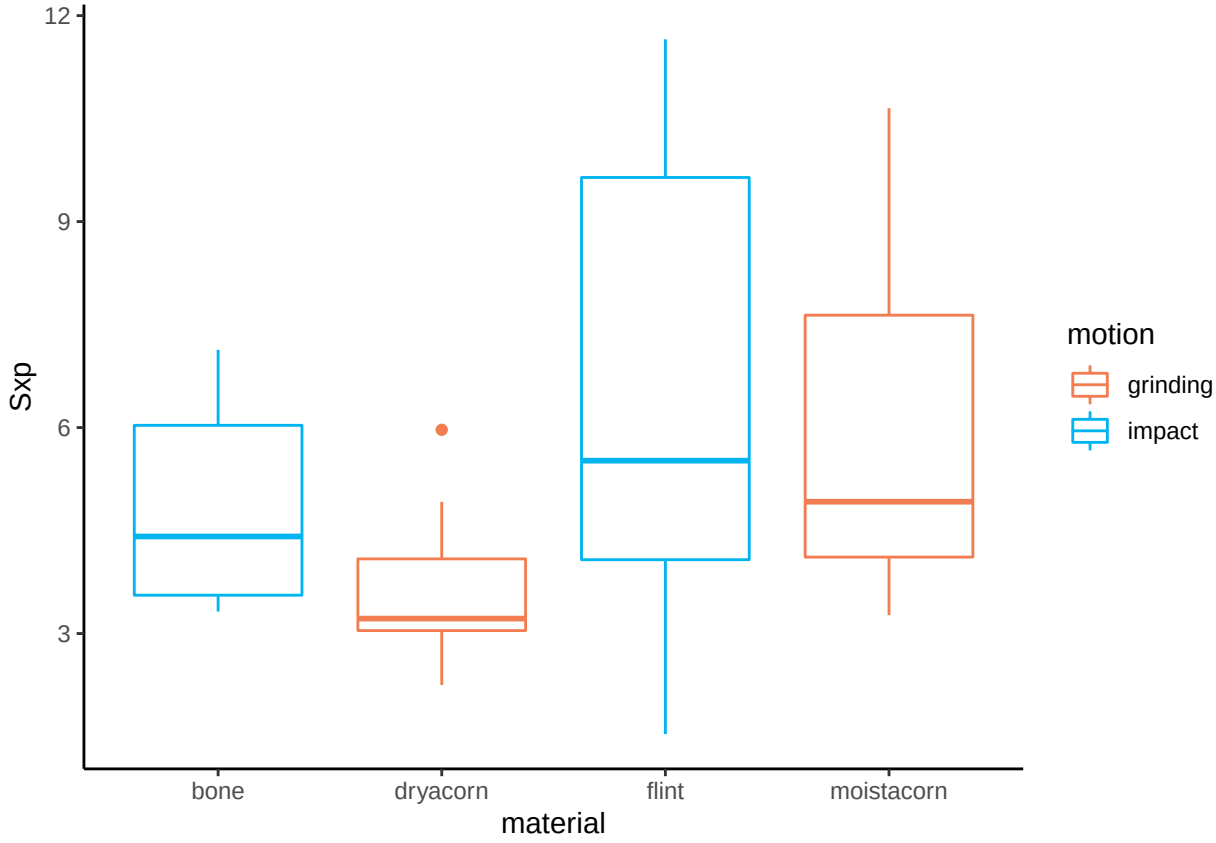

Sv
25
20
15
10
5
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

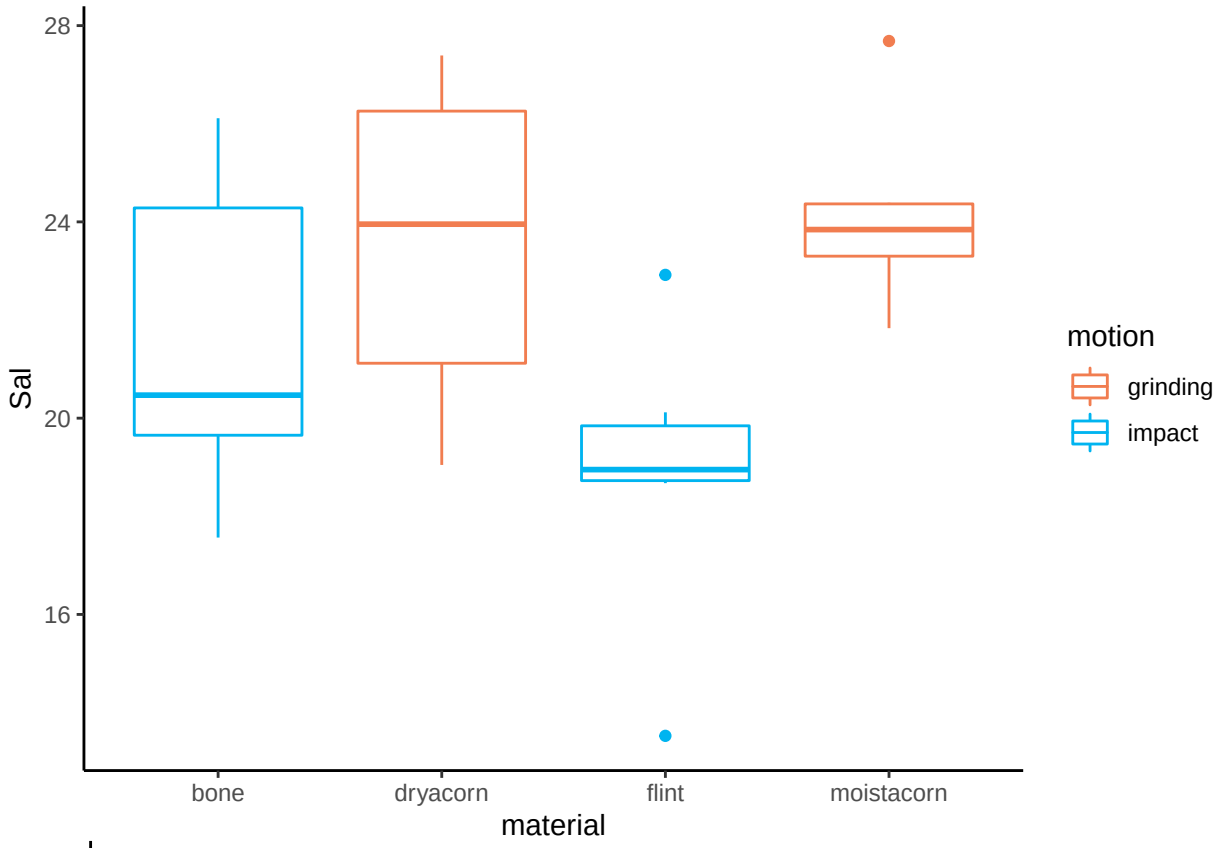

Sz
50
40
30
20
10
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

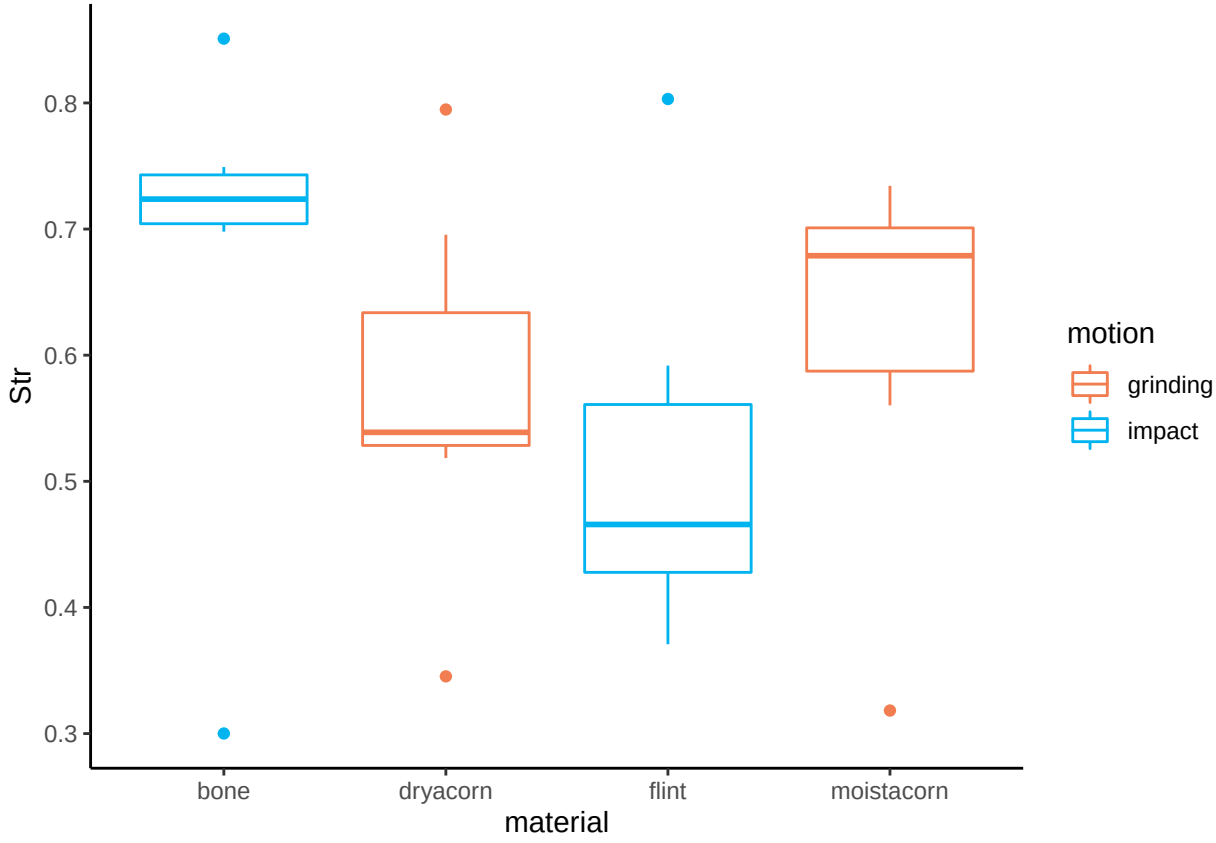

Sa
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

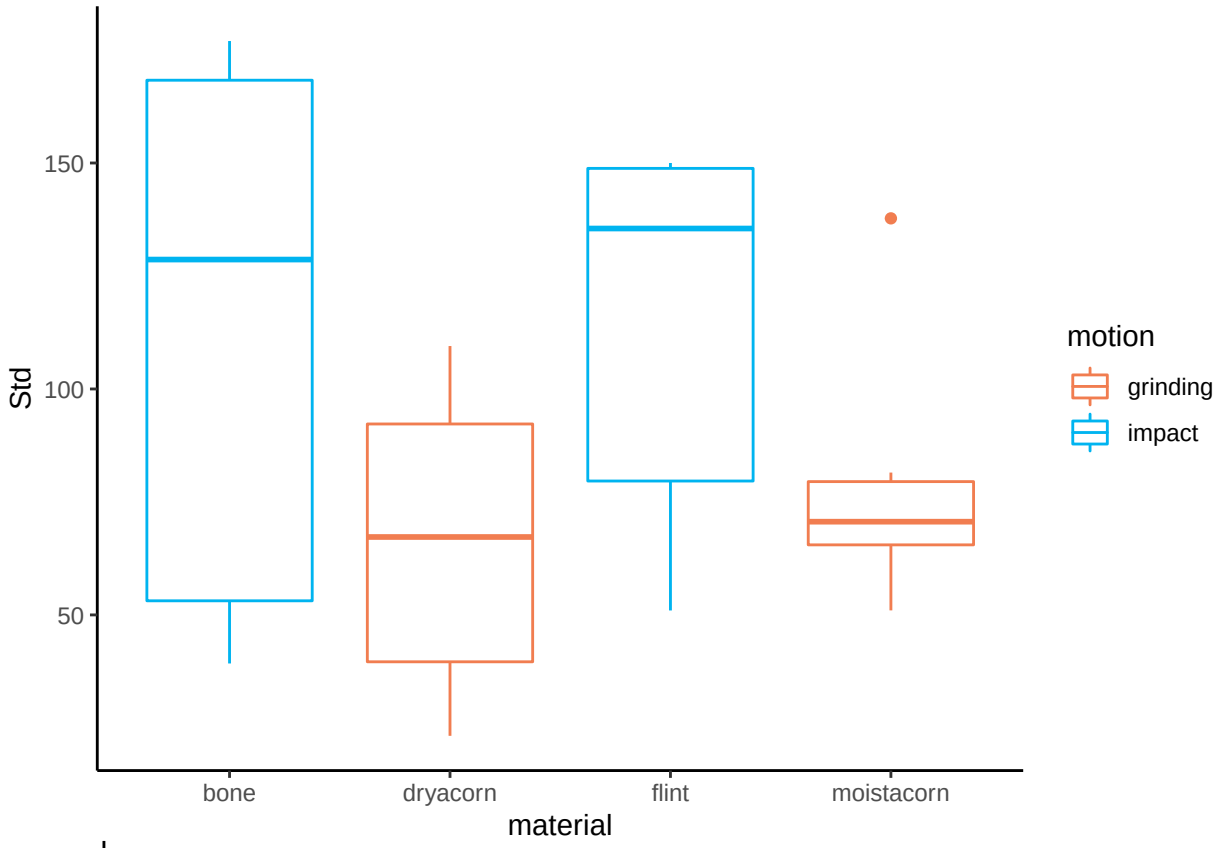

Smr
3
2
1
0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

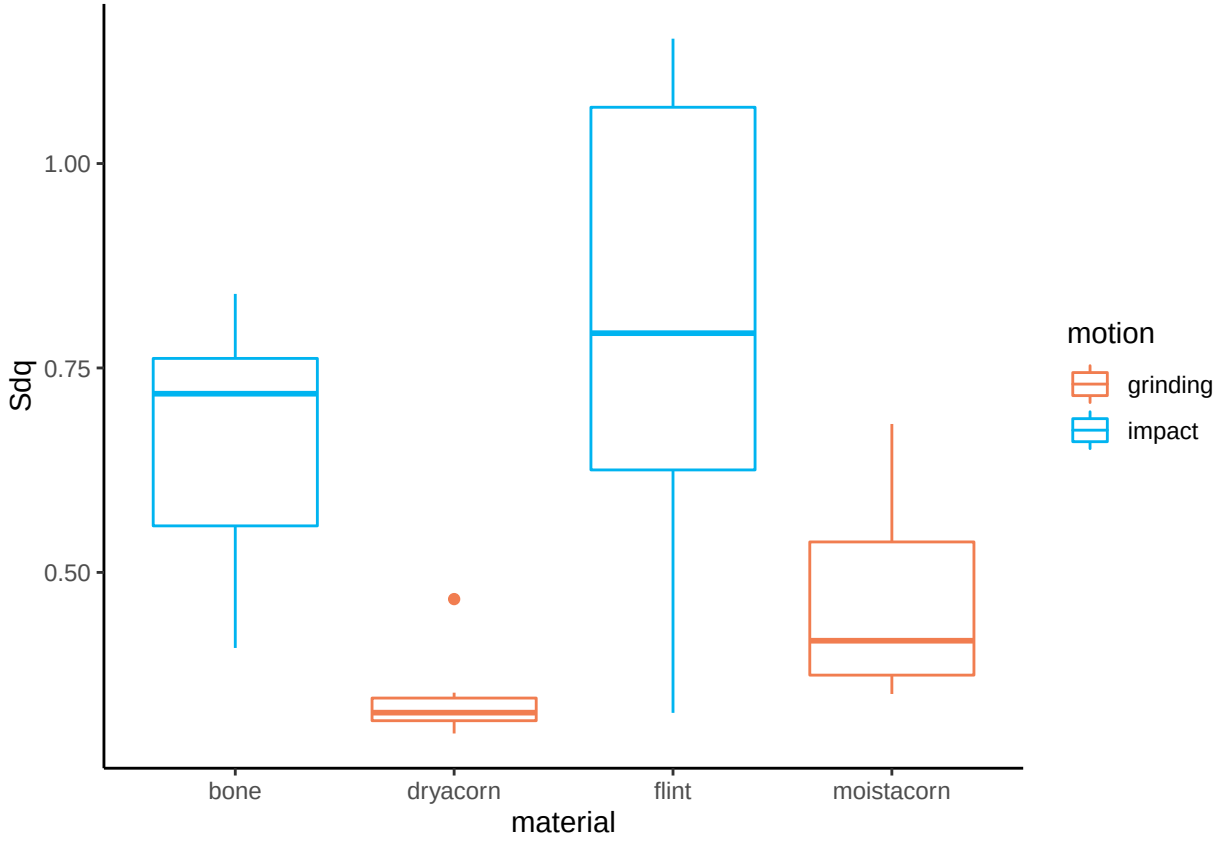

Smc
6
5
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

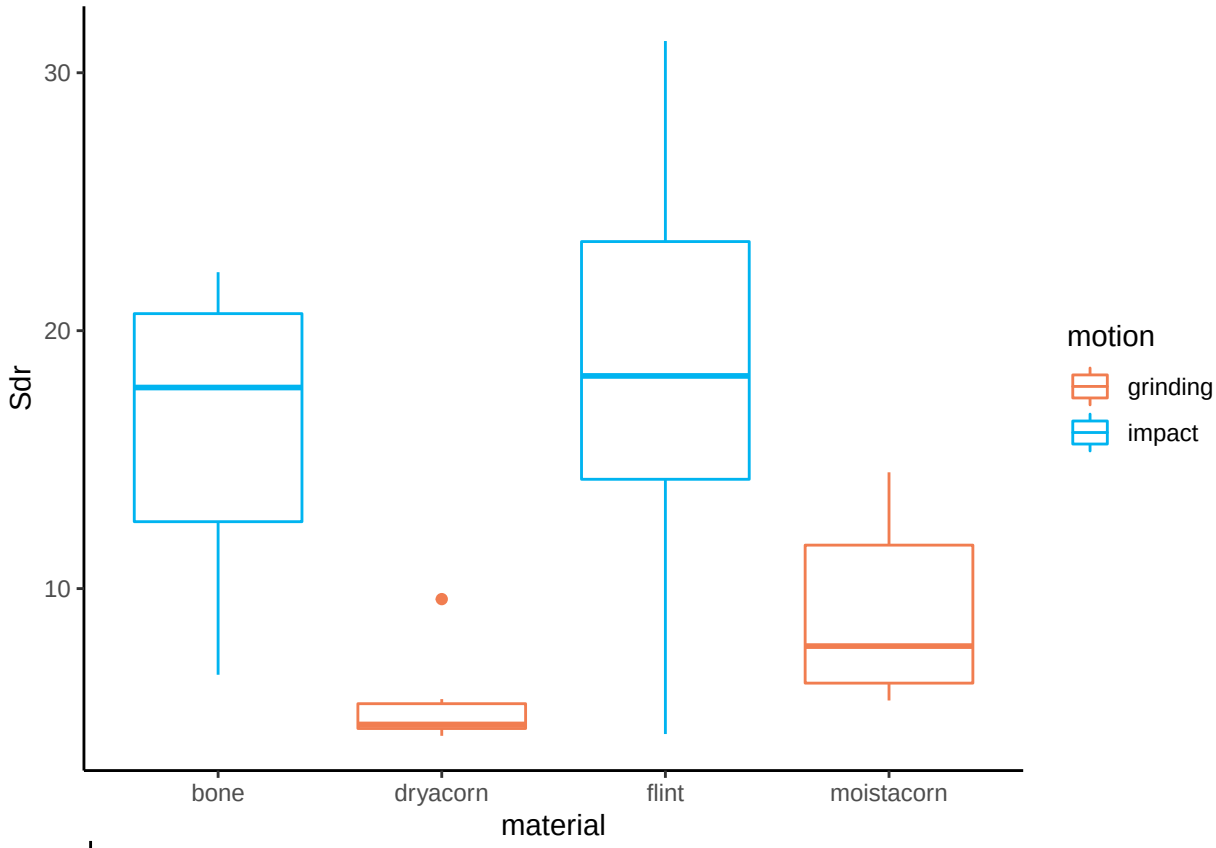

Sxp
12
9
6
3
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

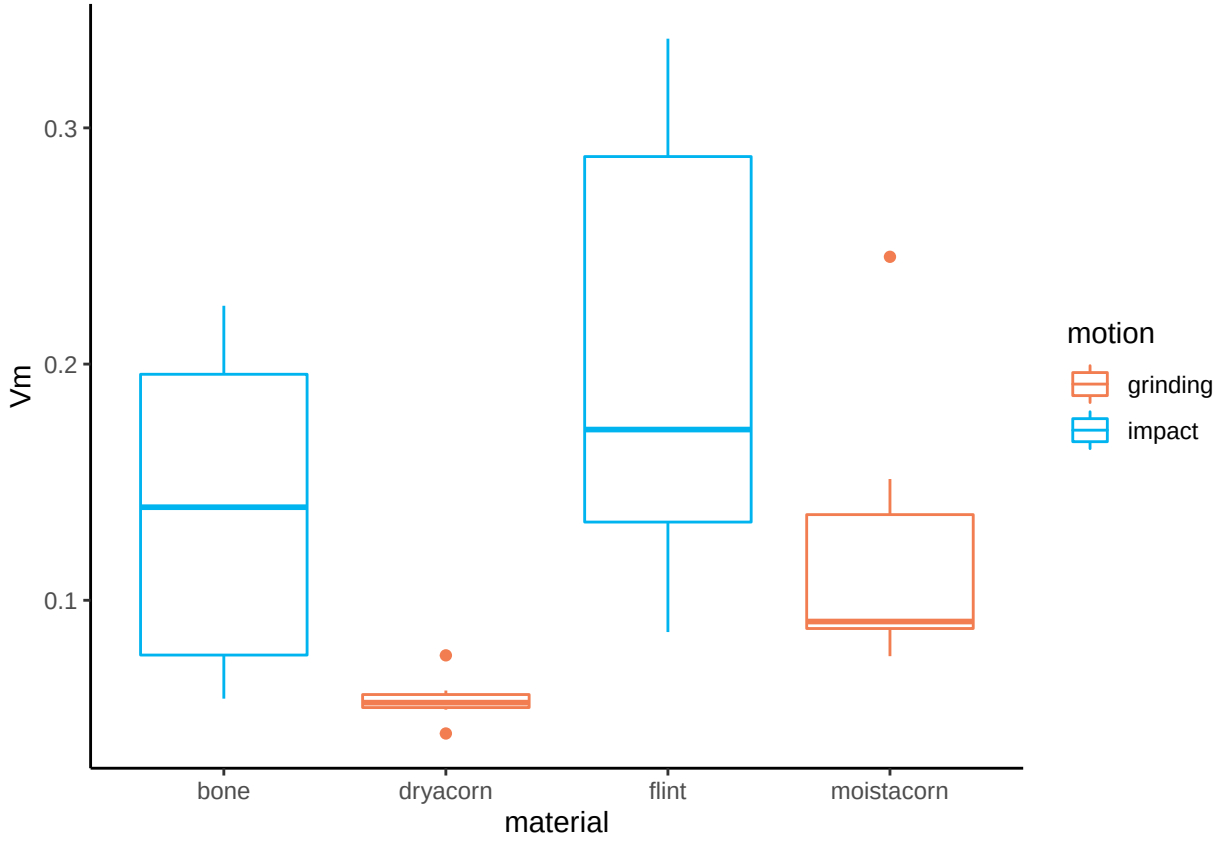

28
24
20
16
Sal
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

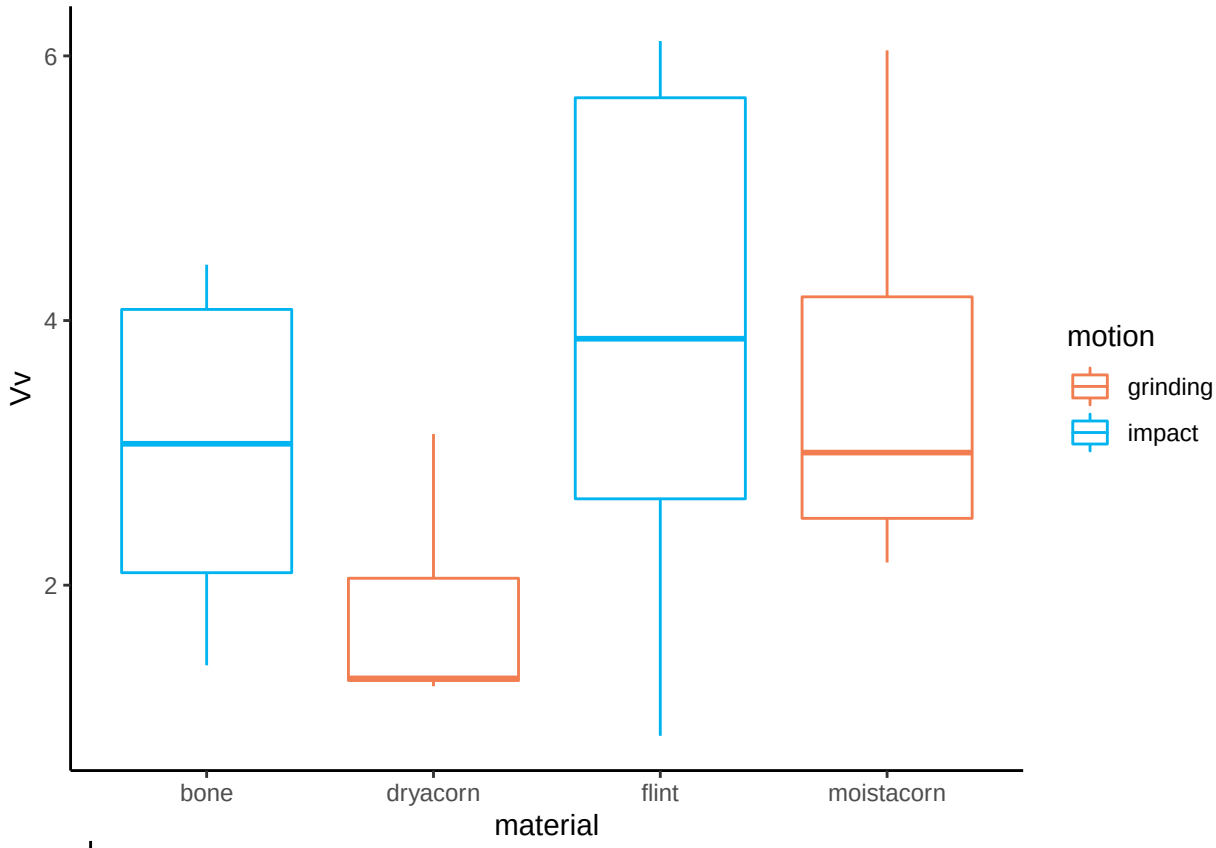

0.8
0.7
0.6
0.5
0.4
0.3
Str
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

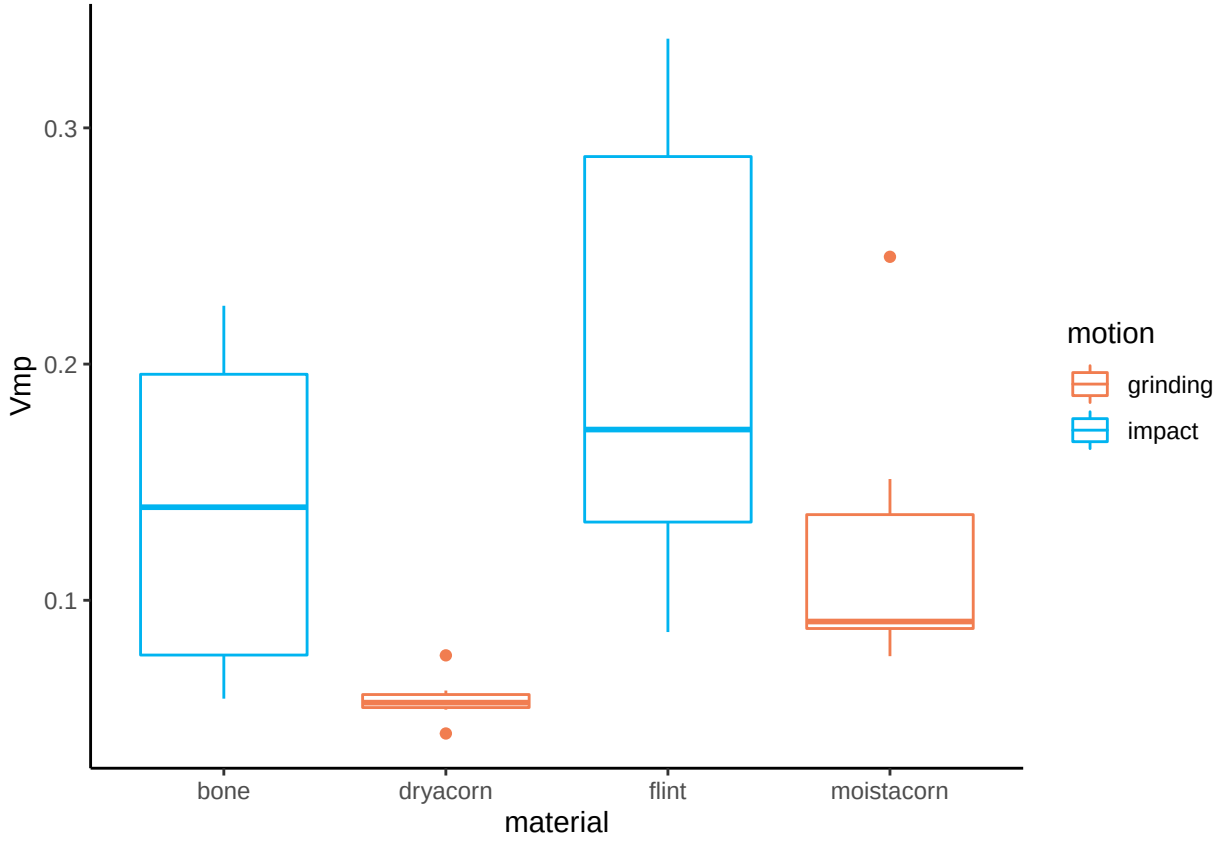

Std
150
100
50
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

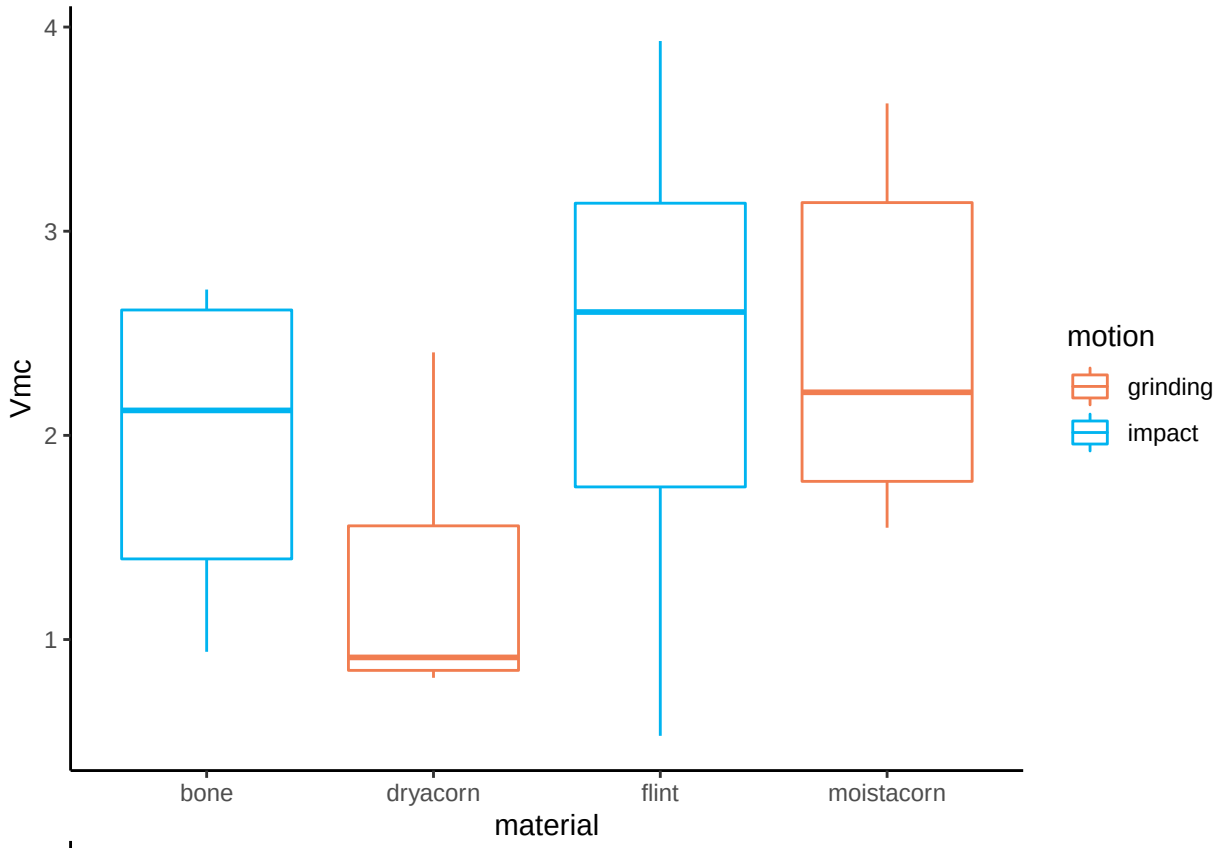

Sdq
1.00
0.75
0.50
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

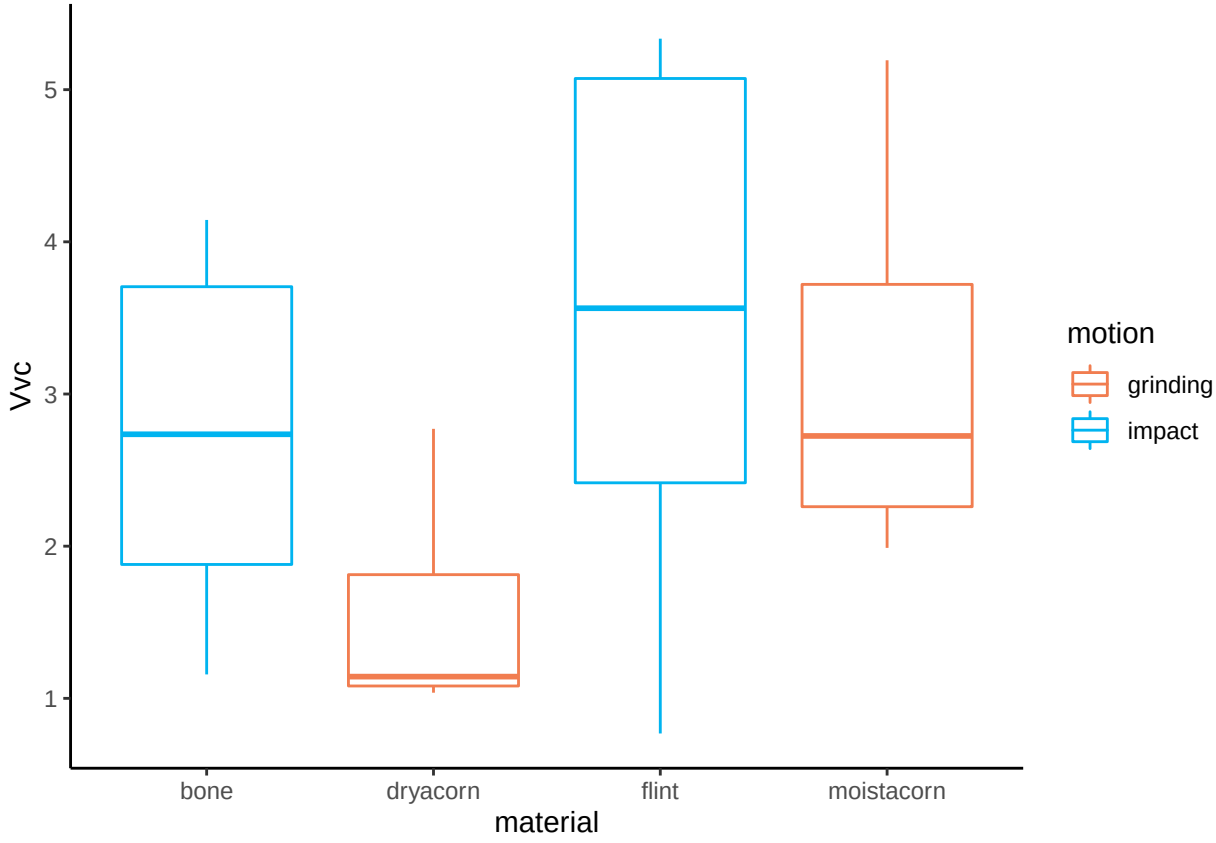

30
20
10
Sdr
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

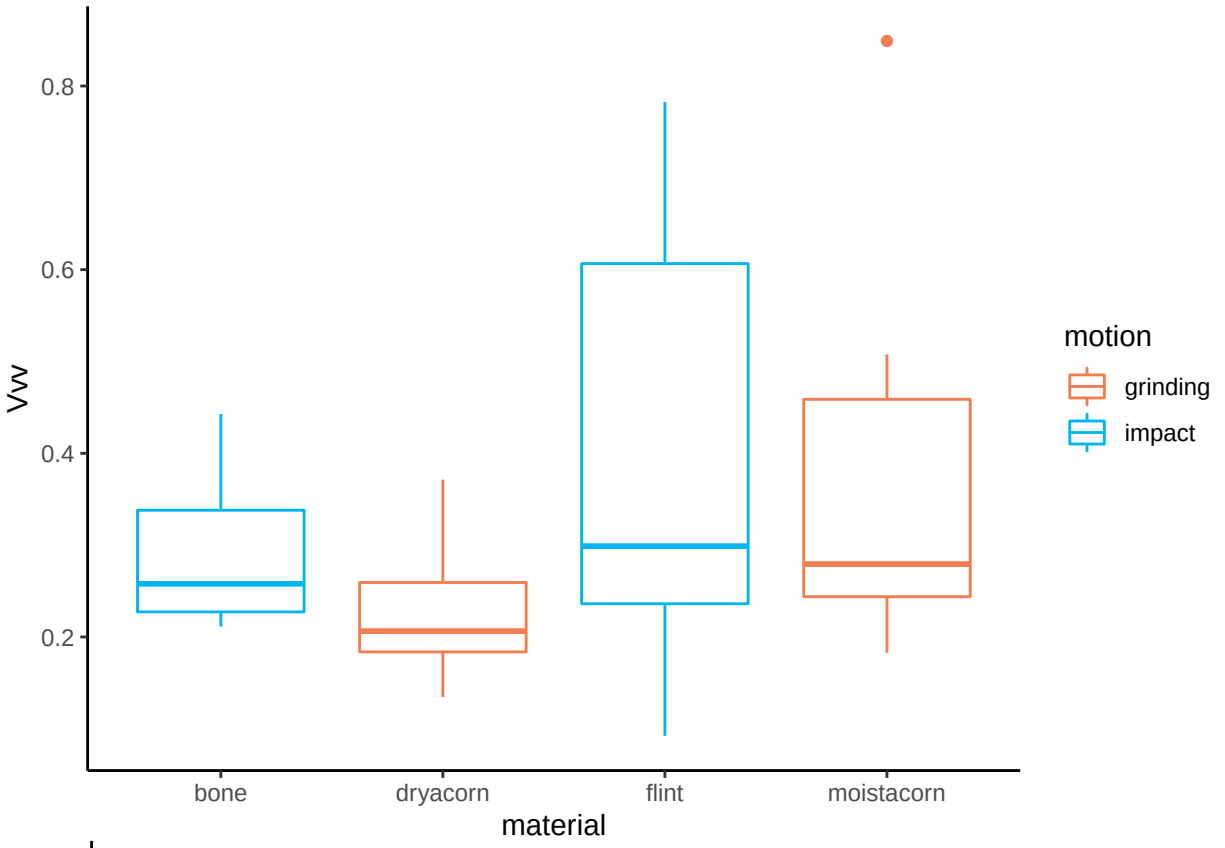

0.3
0.2
0.1
Vm
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

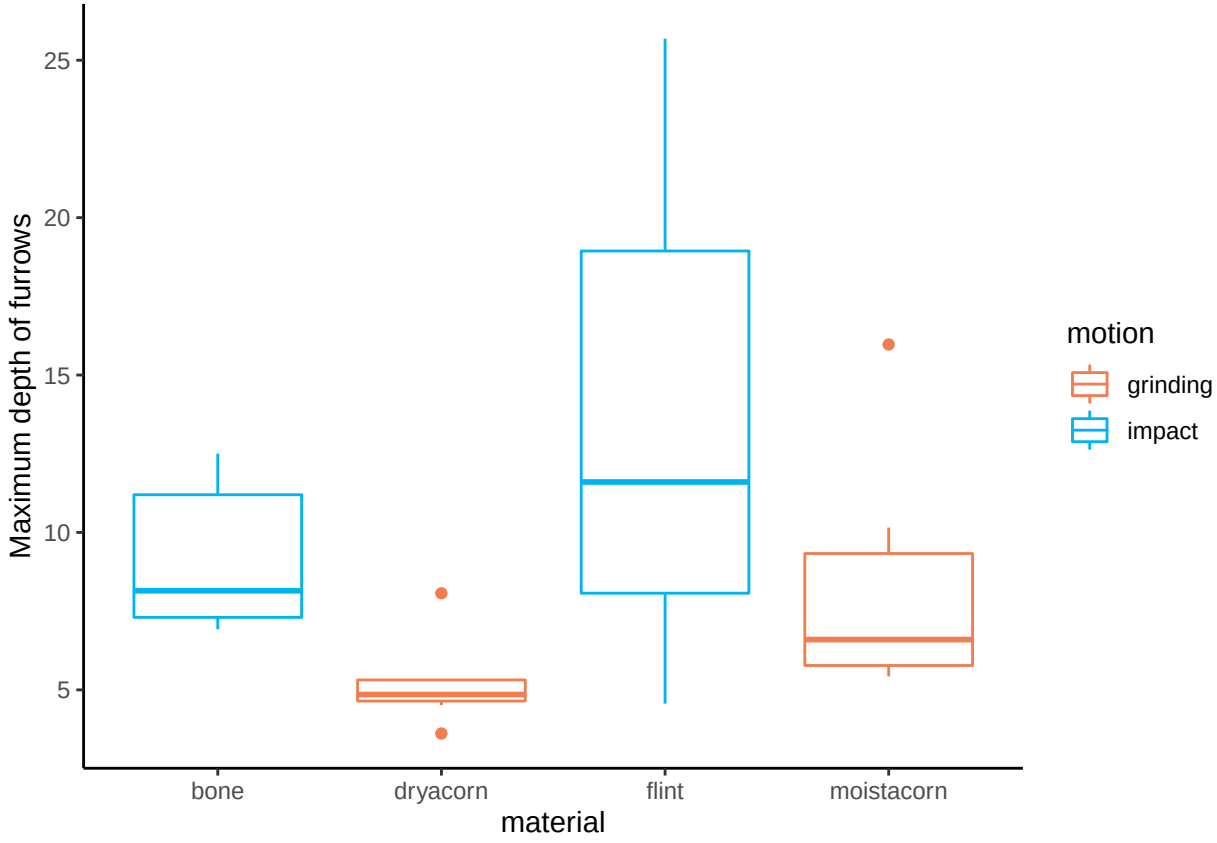

6
4
2
Vv
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

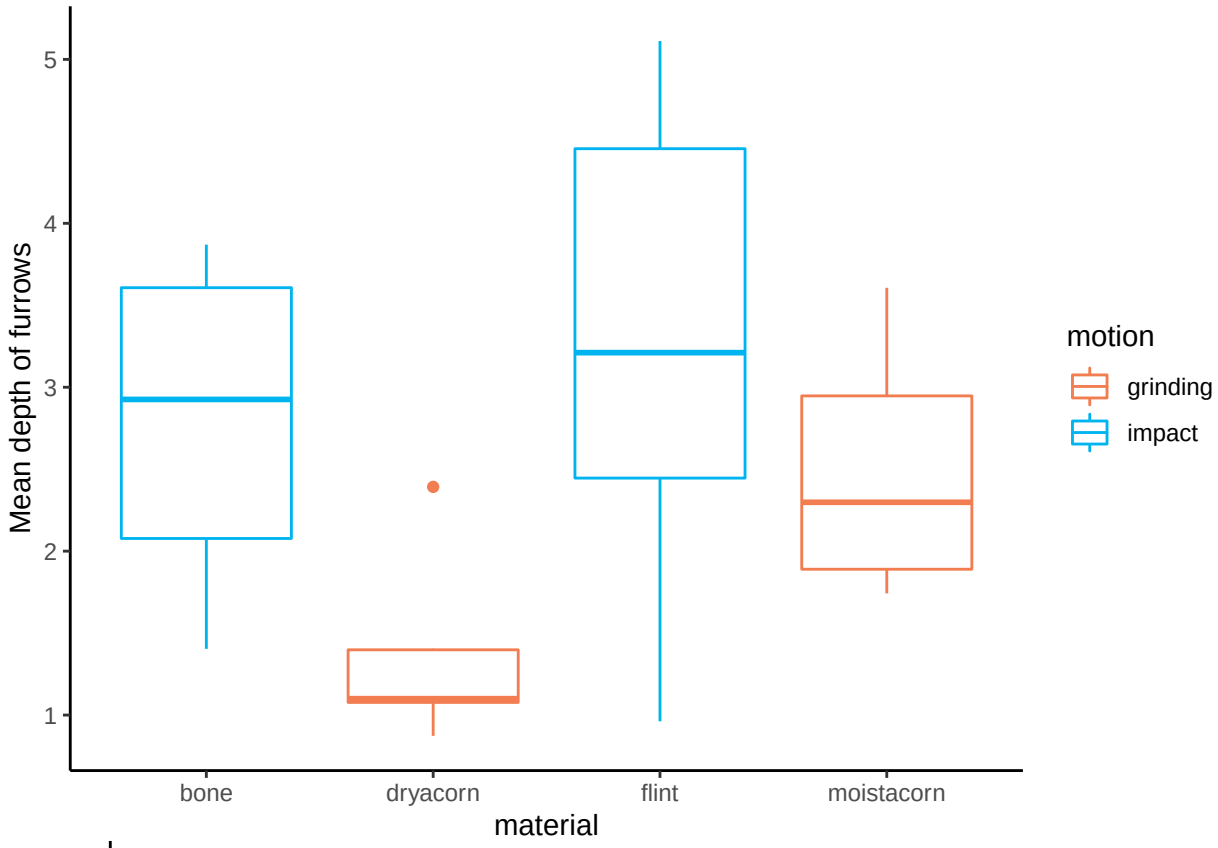

0.3
0.2
0.1
Vmp
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

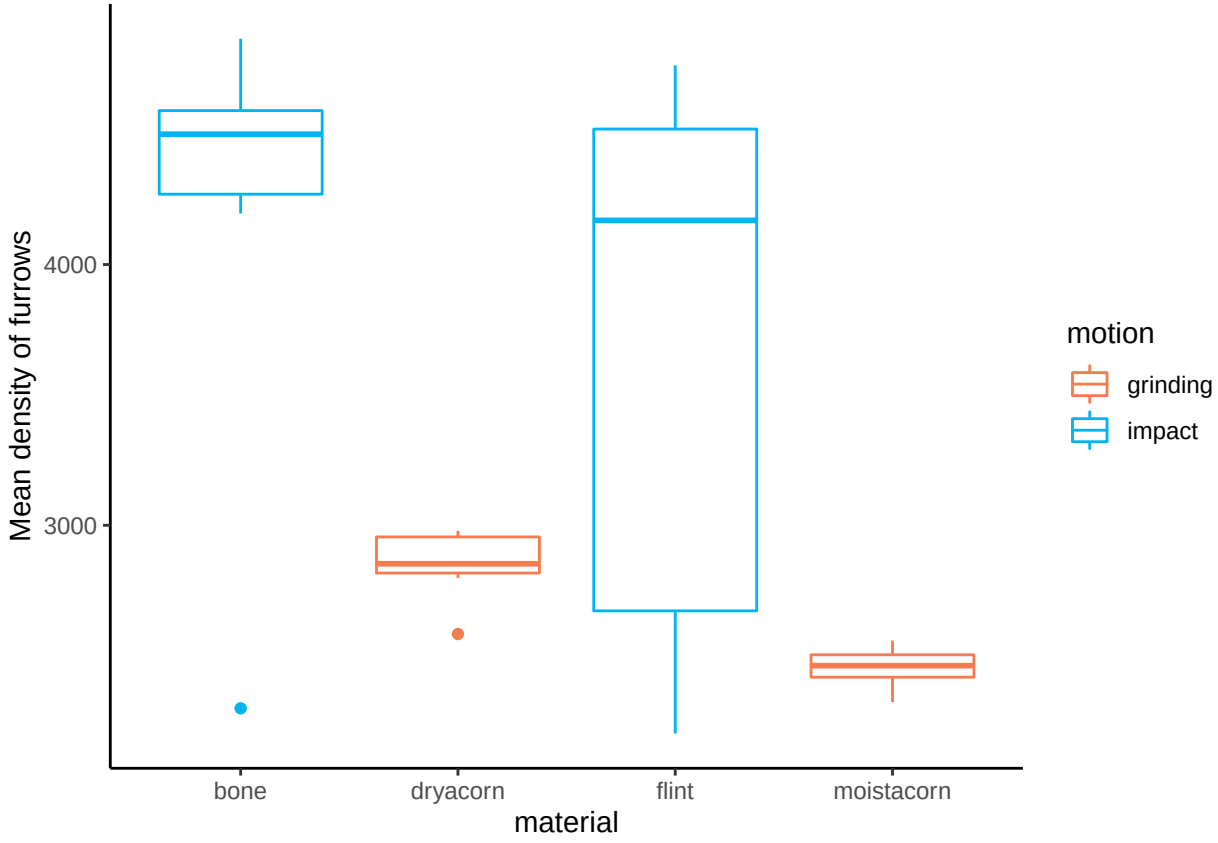

Vmc
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

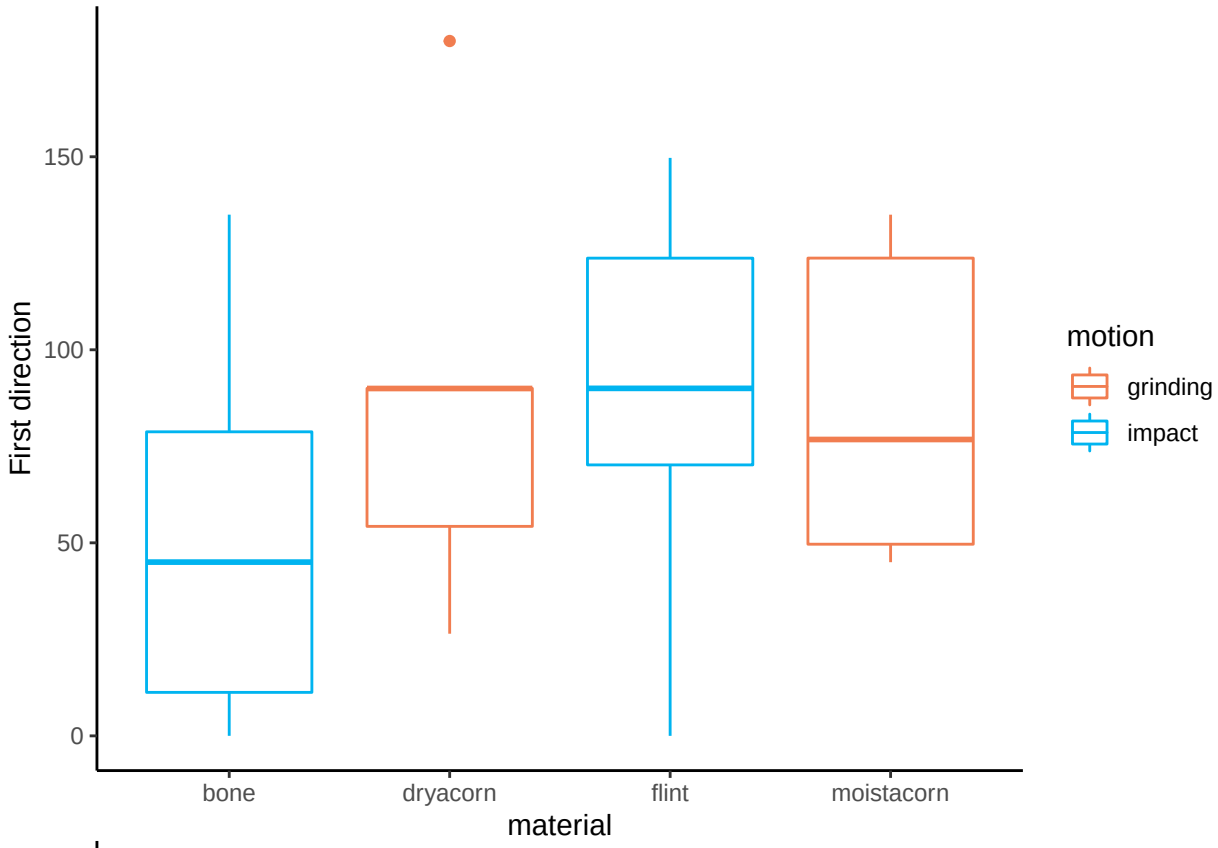

Vvc
5
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

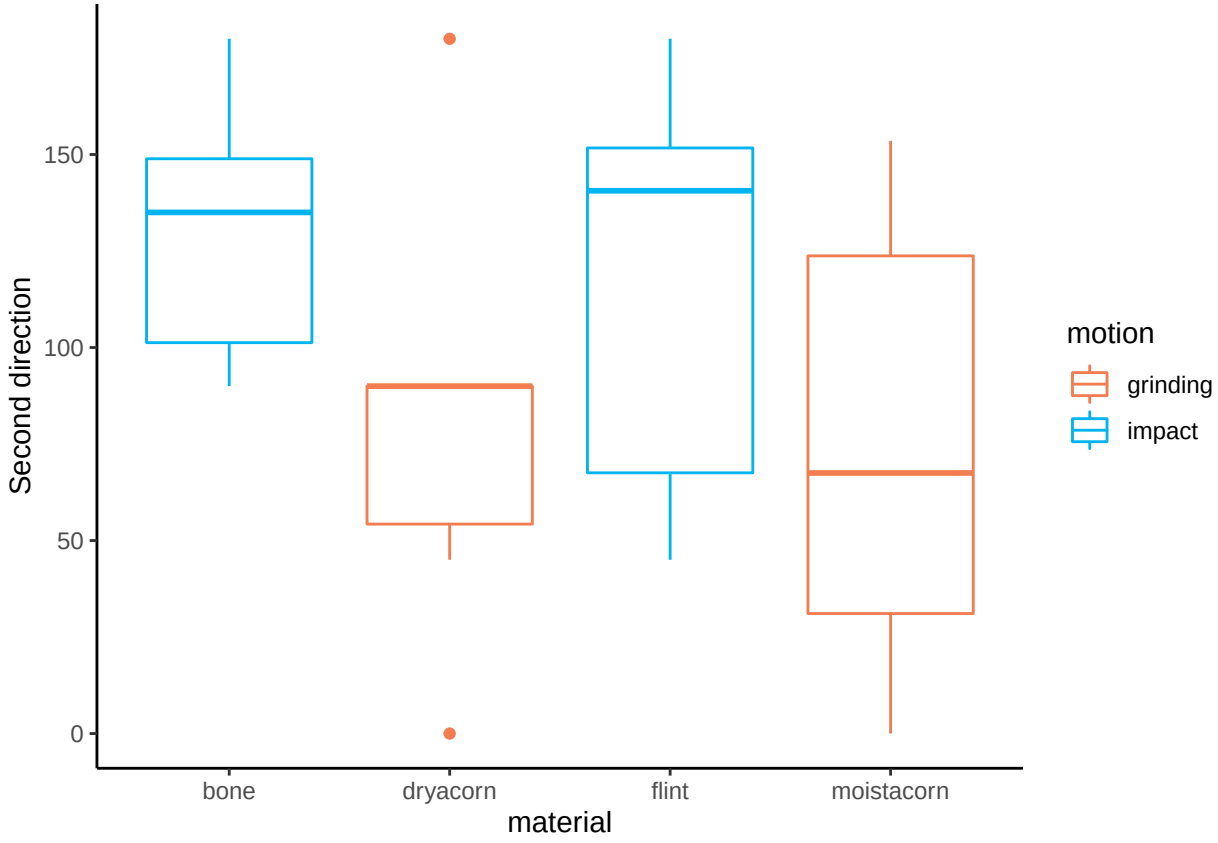

Vvv
0.8
0.6
0.4
0.2
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

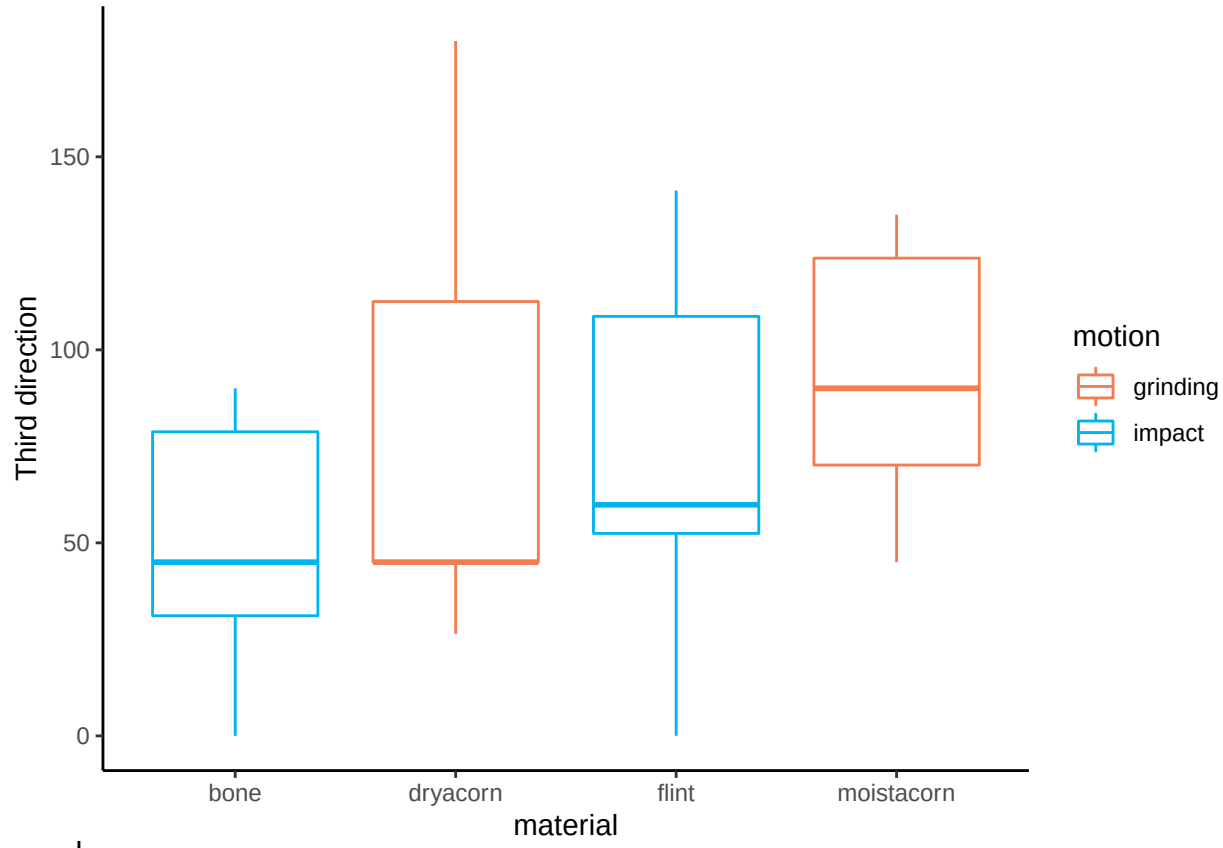

Maximum depth of furrows
25
20
15
10
5
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

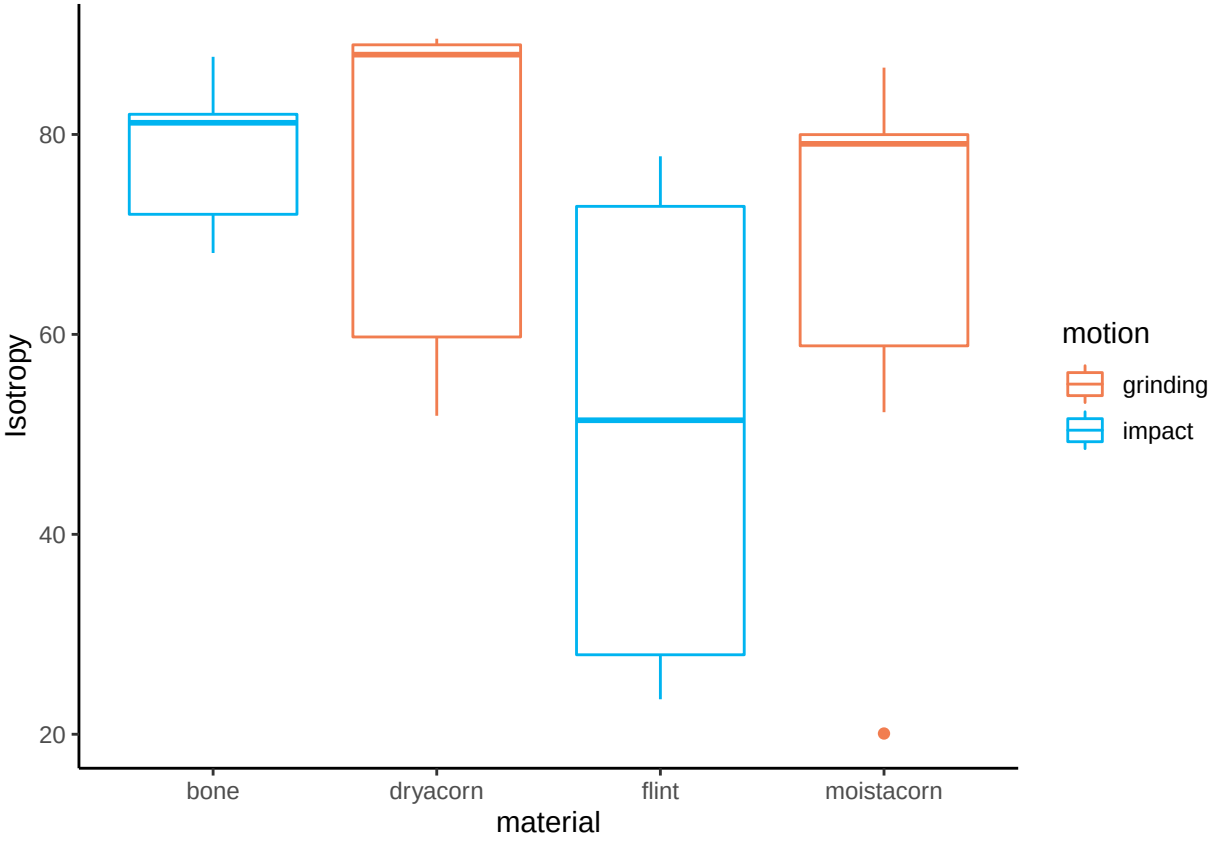

Mean depth of furrows
5
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


Mean density of furrows
4000
3000
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


First direction
150
100
50
0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

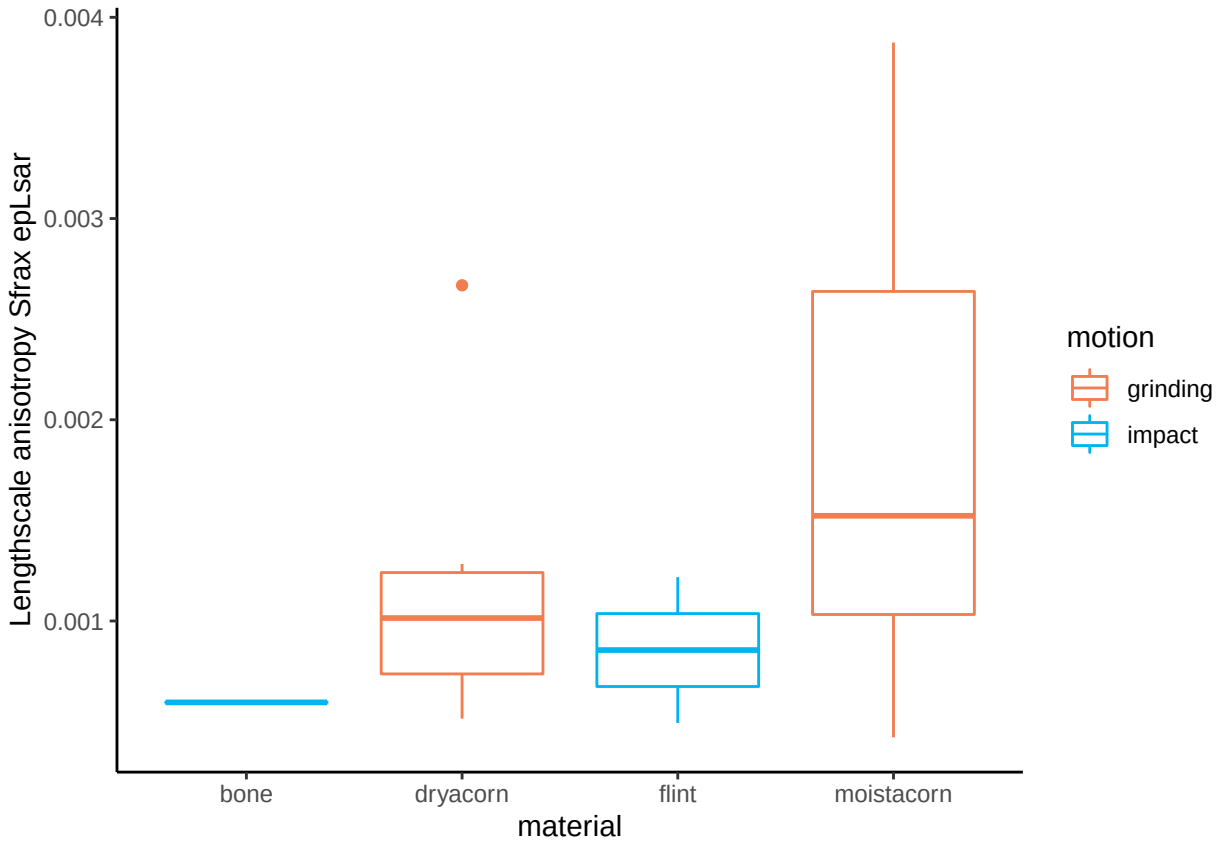

Second direction
150
100
50
0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



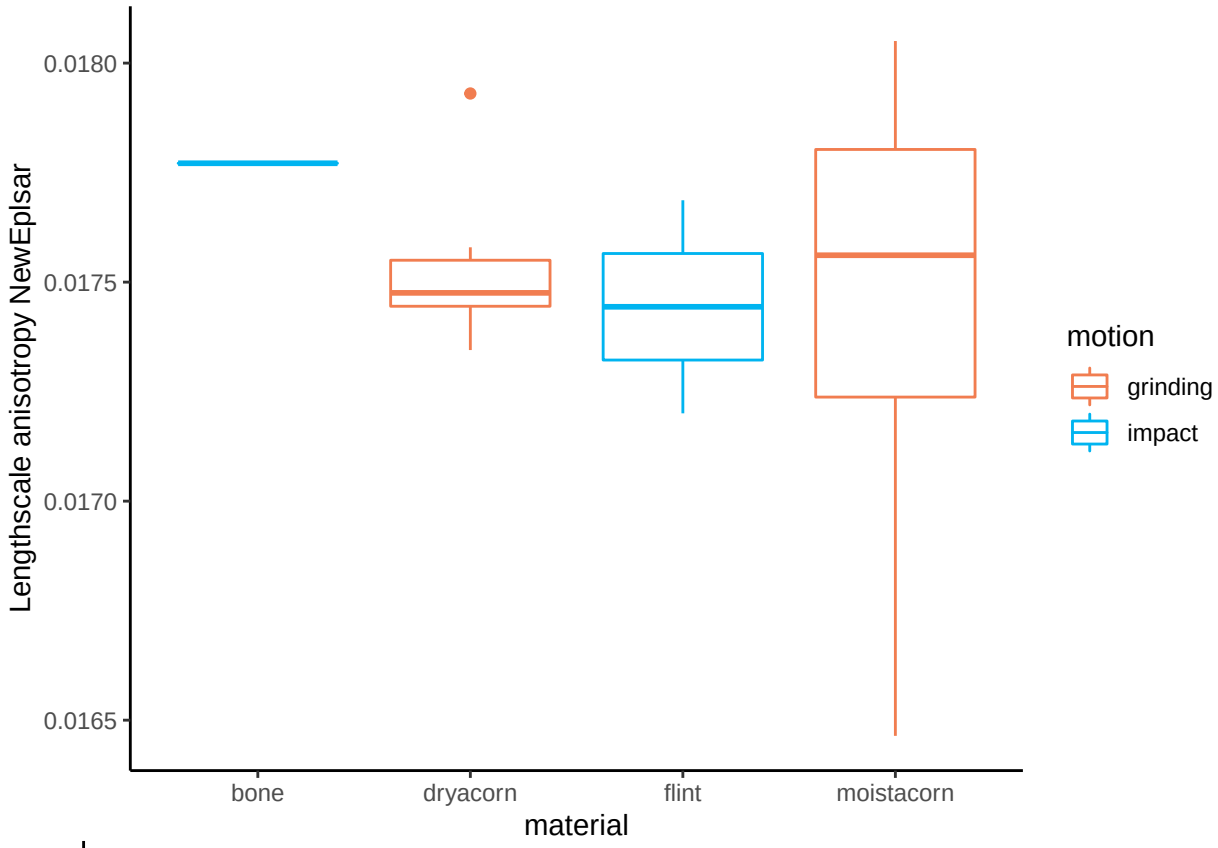


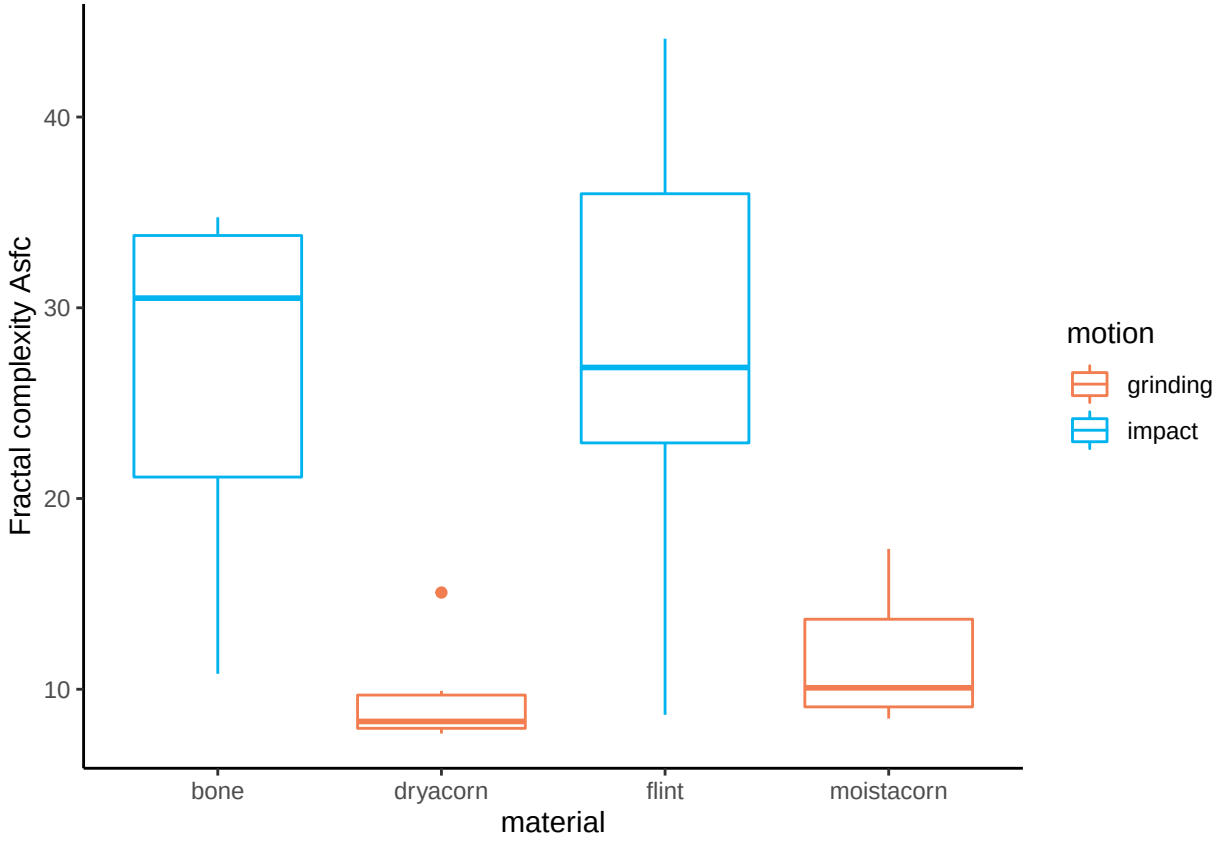

```
## Warning: Removed 9 rows containing non-finite values (stat_boxplot).
```

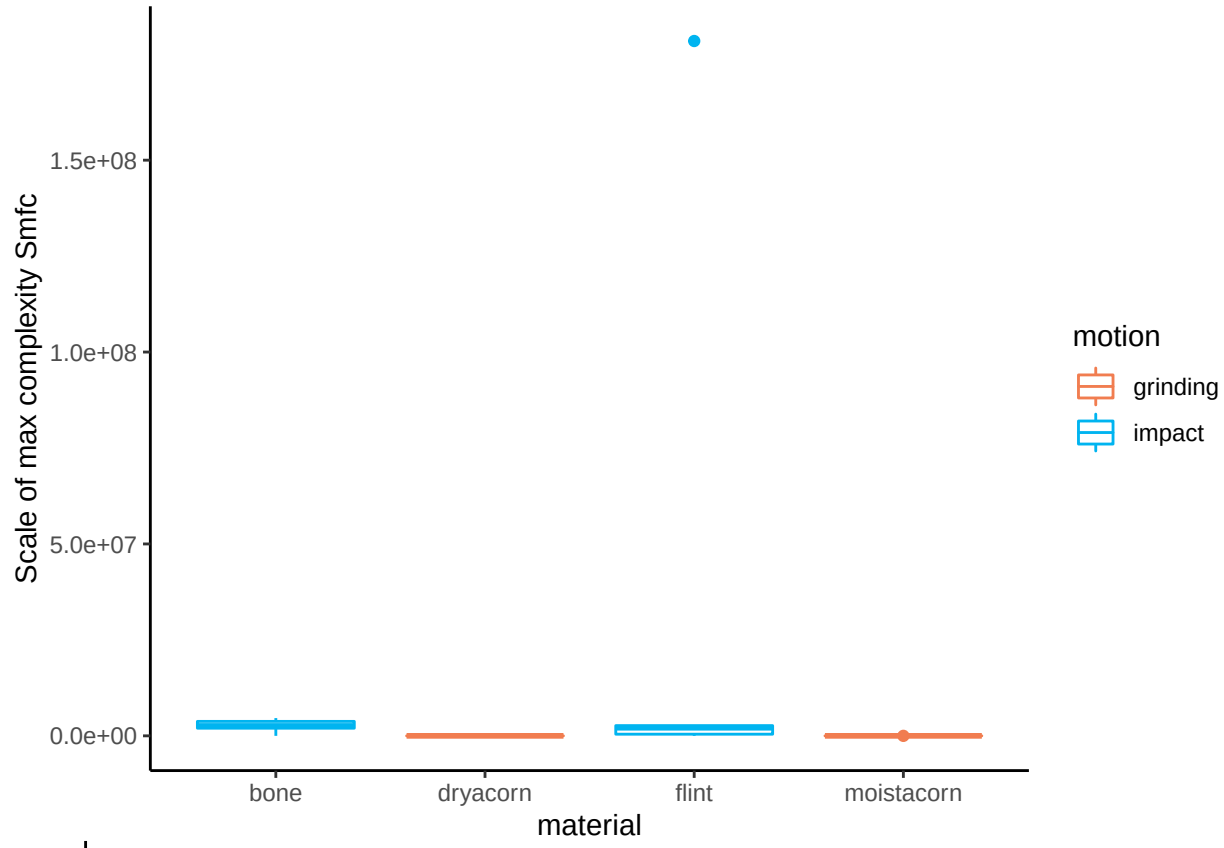
```
## Warning: Removed 9 rows containing non-finite values (stat_boxplot).
```

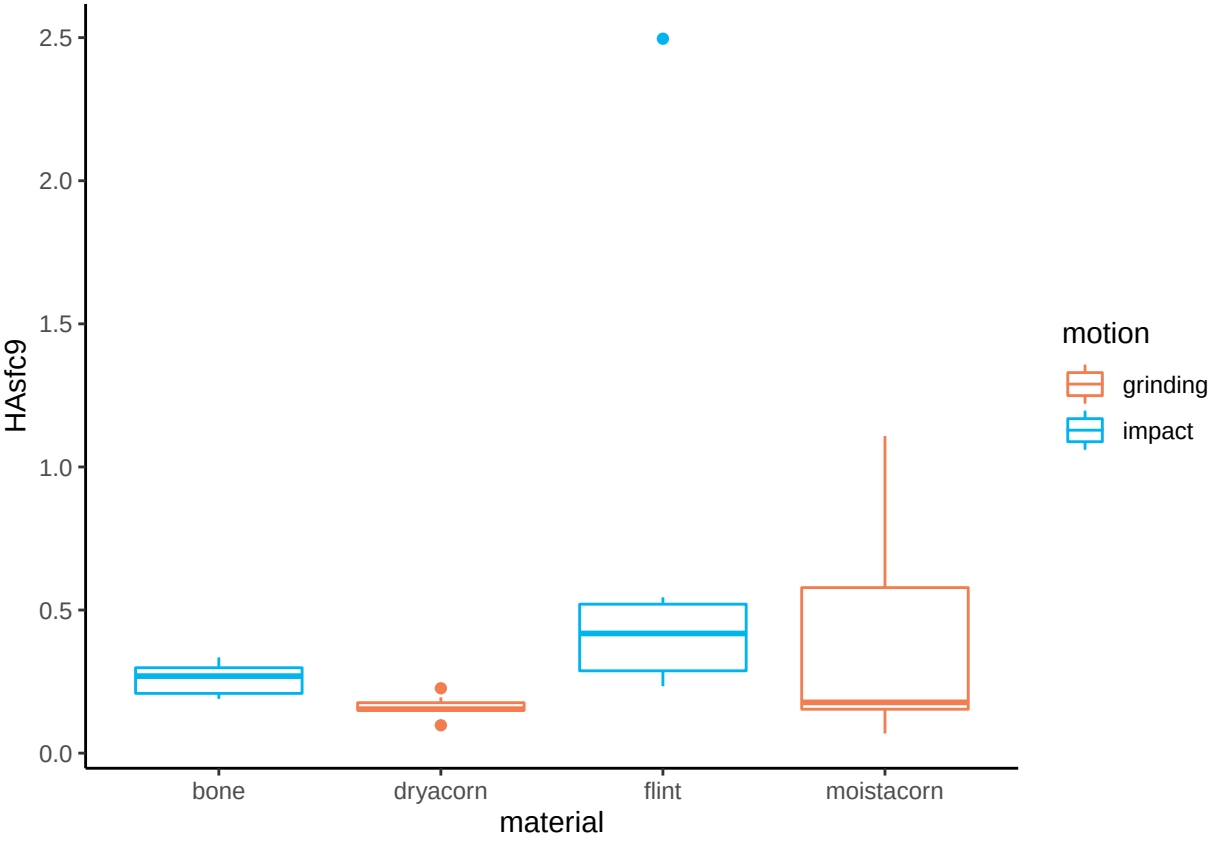


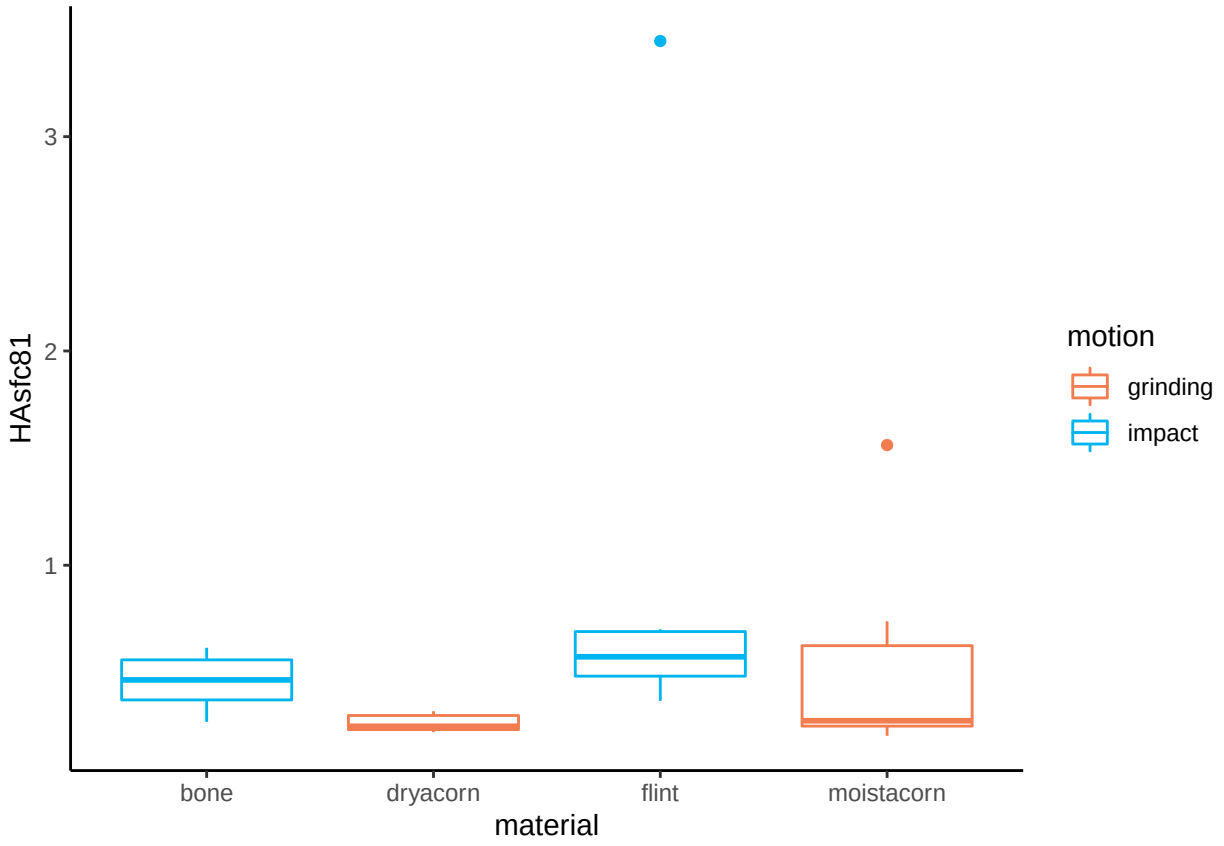

```
## Warning: Removed 9 rows containing non-finite values (stat_boxplot).

## Warning: Removed 9 rows containing non-finite values (stat_boxplot).
```


Lengthscale anisotropy NewEplsar
0.0180
0.0175
0.0170
0.0165
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


Fractal complexity Asfc
40
30
20
10
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

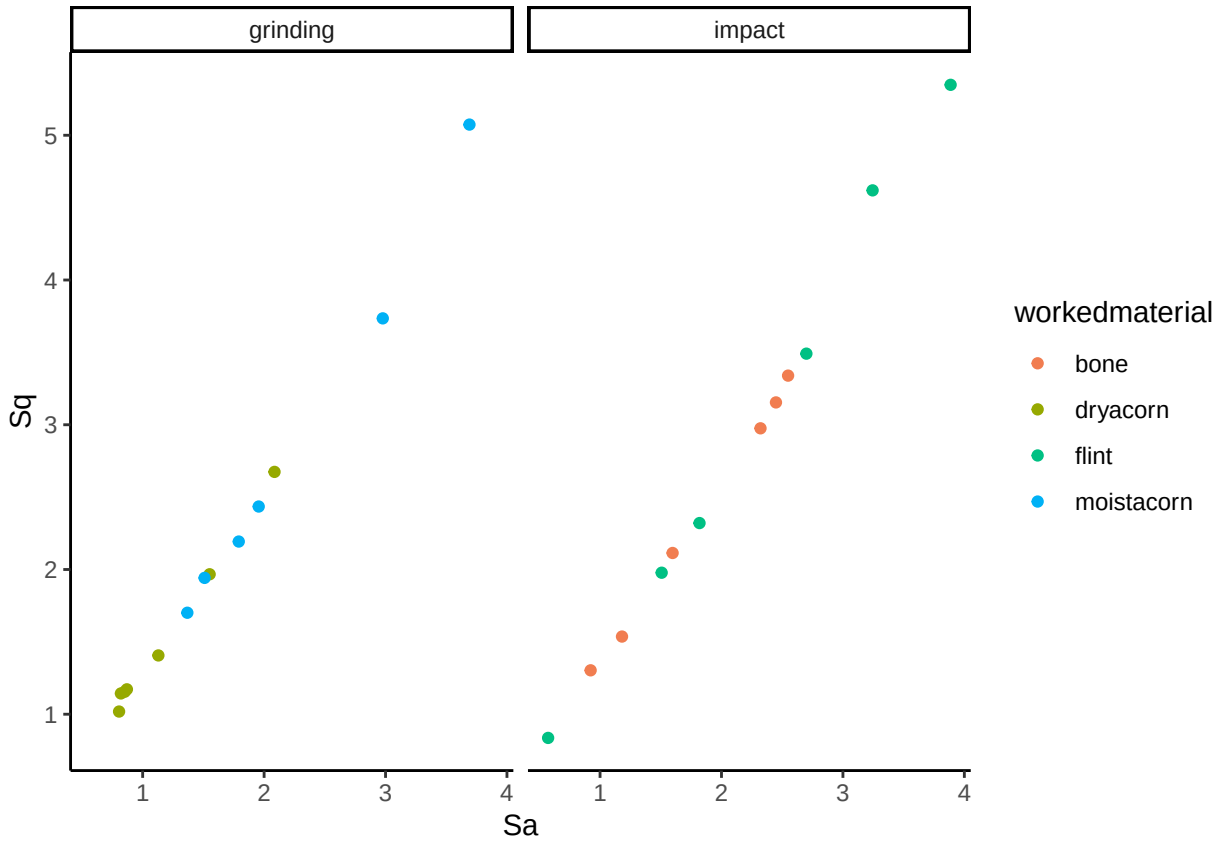

Scale of max complexity Smfc
1.5e+08
1.0e+08
5.0e+07
0.0e+00
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


HAsfc9
2.5
2.0
1.5
1.0
0.5
0.0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



Scatterplots of selected variables combined by "Worked material" and "Motion"

```
# Sa vs. Sq

Sa_Sq <- ggplot(data = confocaldata) +
         geom_point(mapping = aes(x = Sa, y = Sq, colour = workedmaterial)) +
         theme_classic() +
         labs(colour = "workedmaterial") +
         facet_wrap(~ motion) +
         scale_colour_hue(h = c(25, 230))
print(Sa_Sq)
```

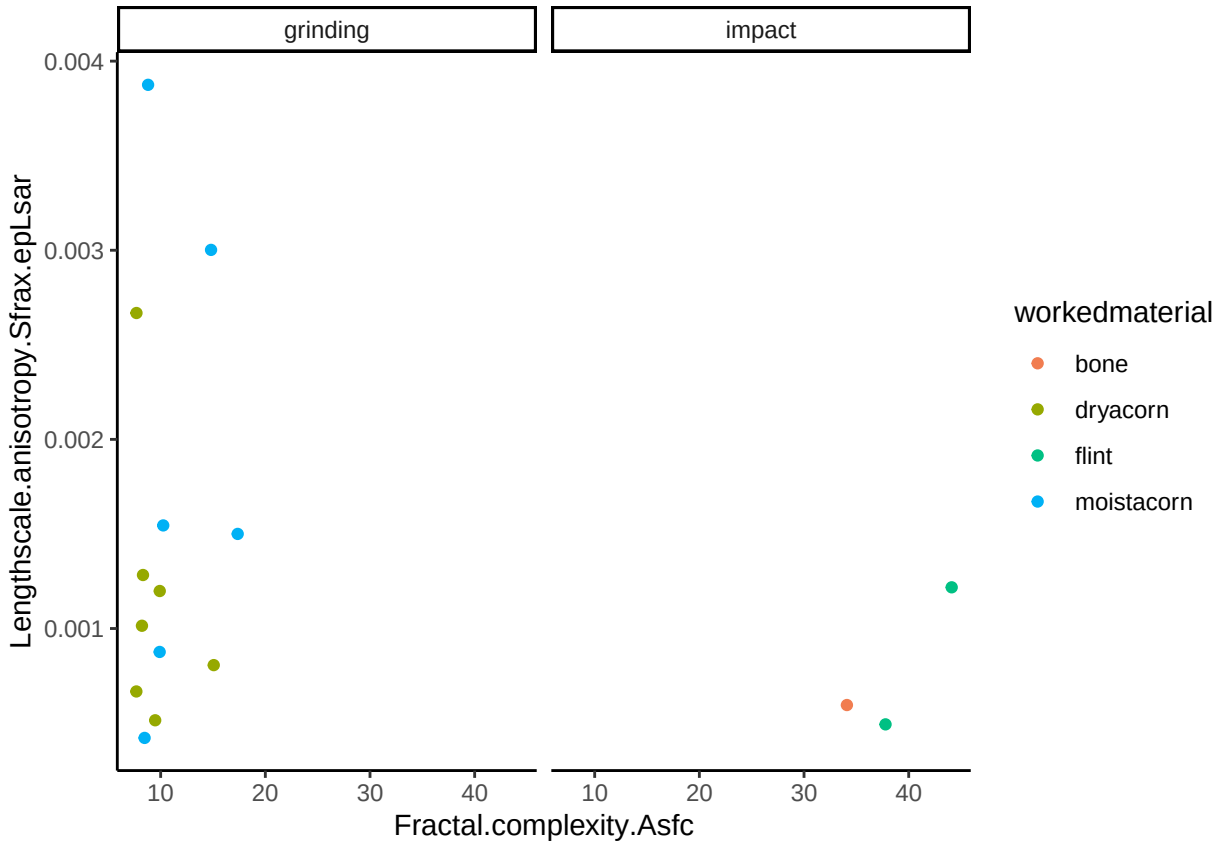



```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sa-Sq", ".pdf")
ggsave(filename = file_out, plot = Sa_Sq, path = "../plots", device = "pdf")
```

```
## Saving 6.5 x 4.5 in image
```

```
# epLsar vs. Asfc

ep_As <- ggplot(data = confocaldata) +
         geom_point(mapping = aes(x = Fractal.complexity.Asfc, y = Lengthscale.anisotropy.Sfrax.epLsar,
         theme_classic() +
         labs(colour = "workedmaterial") +
         facet_wrap(~ motion) +
         scale_colour_hue(h = c(25, 230))
print(ep_As)
```

```
## Warning: Removed 9 rows containing missing values (geom_point).
```

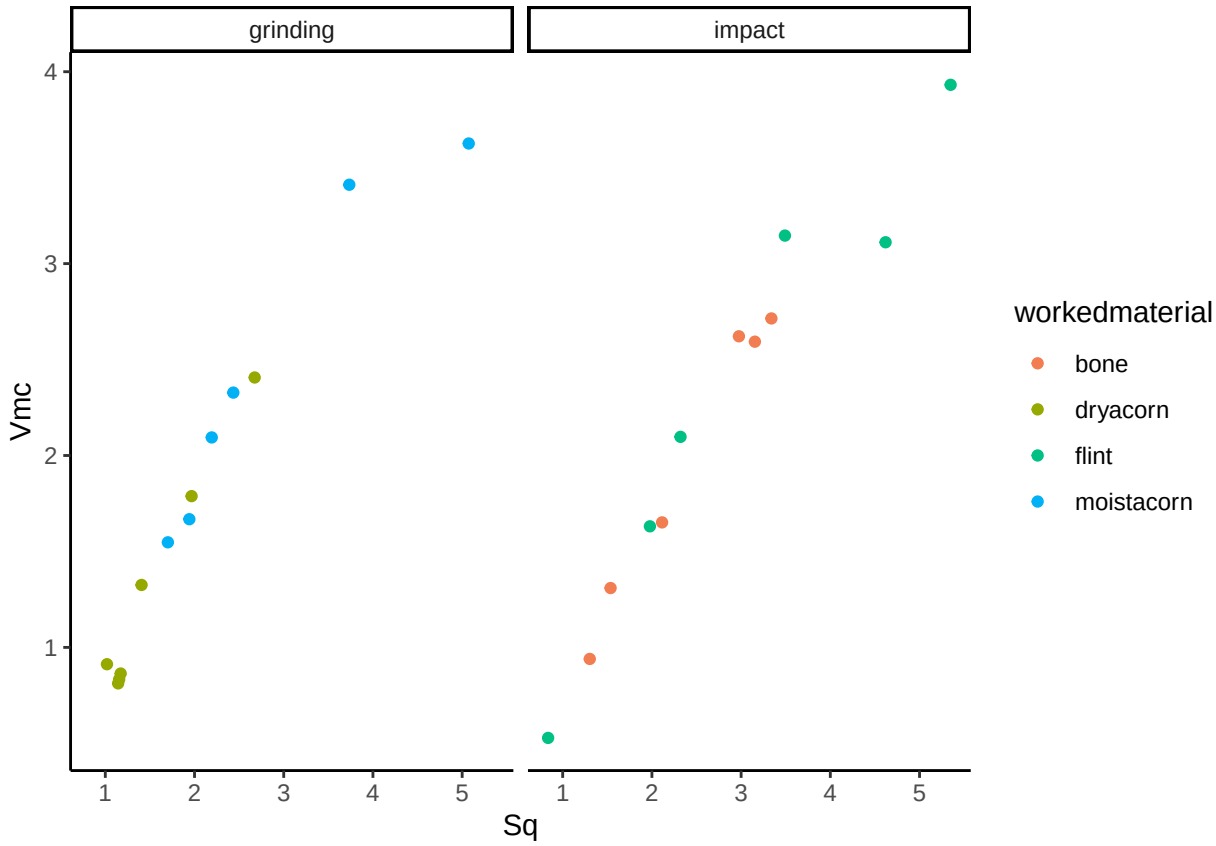



```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Asfc-epLsar", ".pdf")
ggsave(filename = file_out, plot = ep_As, path = "../plots", device = "pdf")
```

```
## Saving 6.5 x 4.5 in image
```

```
## Warning: Removed 9 rows containing missing values (geom_point).
```

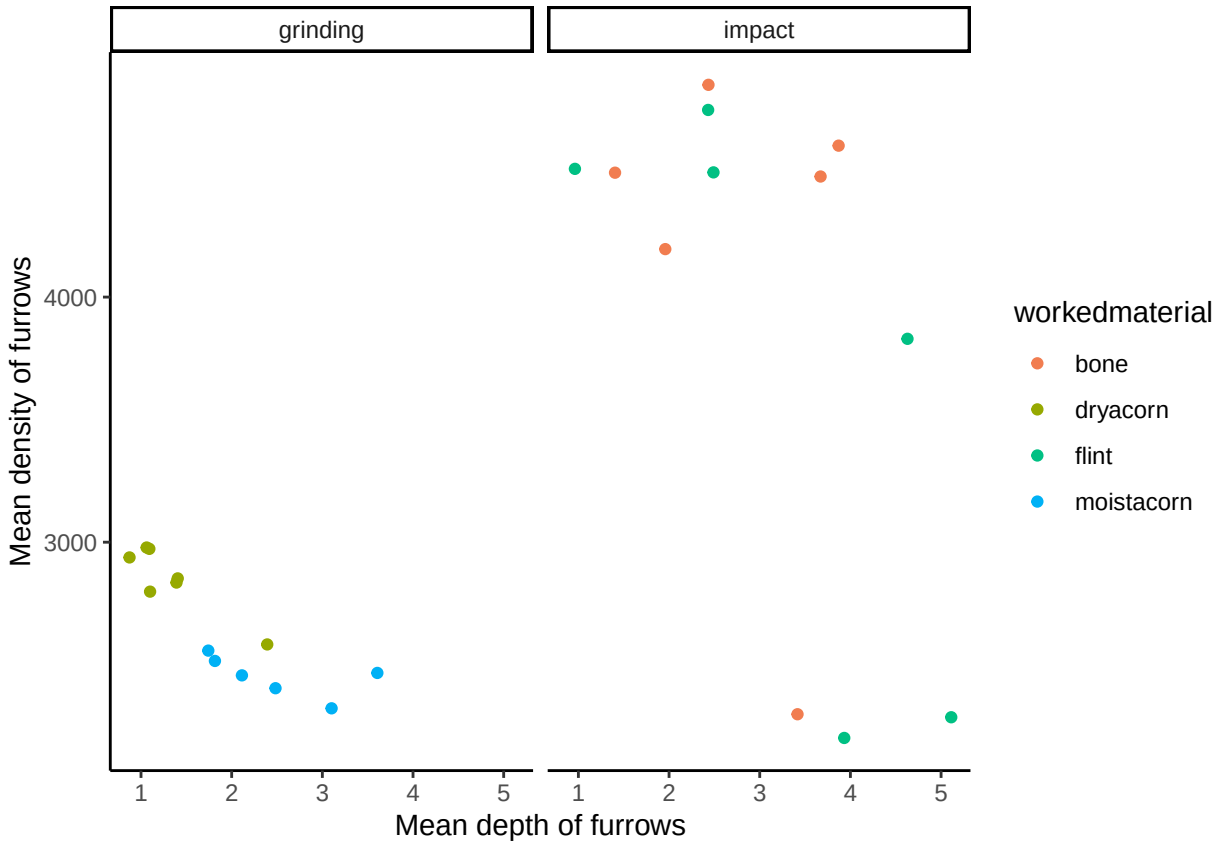
```
# Sq vs. Vmc

Sq_Vmc <- ggplot(data = confocaldata) +
          geom_point(mapping = aes(x = Sq, y = Vmc, colour = workedmaterial)) +
          theme_classic() +
          labs(colour = "workedmaterial") +
          facet_wrap(~ motion) +
          scale_colour_hue(h = c(25, 230))
print(Sq_Vmc)
```




```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sq-Vmc", ".pdf")
ggsave(filename = file_out, plot = Sq_Vmc, path = "../plots", device = "pdf")
```

```
## Saving 6.5 x 4.5 in image
```

```
# Mean depth of furrows vs. mean density of furrows

furrows <- ggplot(data = confocaldata) +
           geom_point(mapping = aes(x = Mean.depth.of.furrows, y = Mean.density.of.furrows,
                                    colour = workedmaterial)) +
           theme_classic() +
           labs(colour = "workedmaterial", x = "Mean depth of furrows", y = "Mean density of furrows") +
           facet_wrap(~ motion) +
           scale_colour_hue(h = c(25, 230))
print(furrows)
```

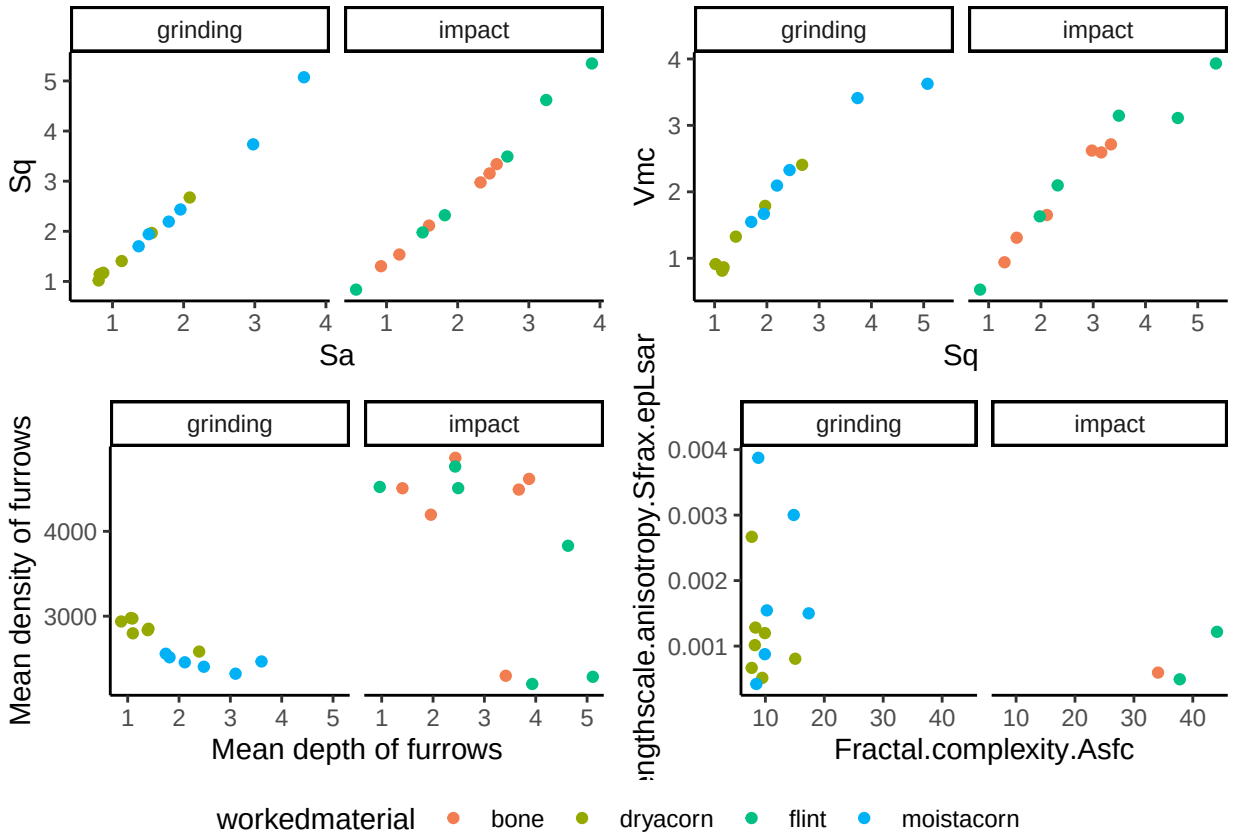



```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_furrows", ".pdf")
ggsave(filename = file_out, plot = furrows, path = "../plots", device = "pdf")
```

```
## Saving 6.5 x 4.5 in image
```

```
# combine all in a single image

ggarrange(Sa_Sq, Sq_Vmc, furrows, ep_As, common.legend = TRUE, legend = "bottom")
```

```
## Warning: Removed 9 rows containing missing values (geom_point).
```




```
ggsave("../plots/confocalscatterplotsexp.png")
```

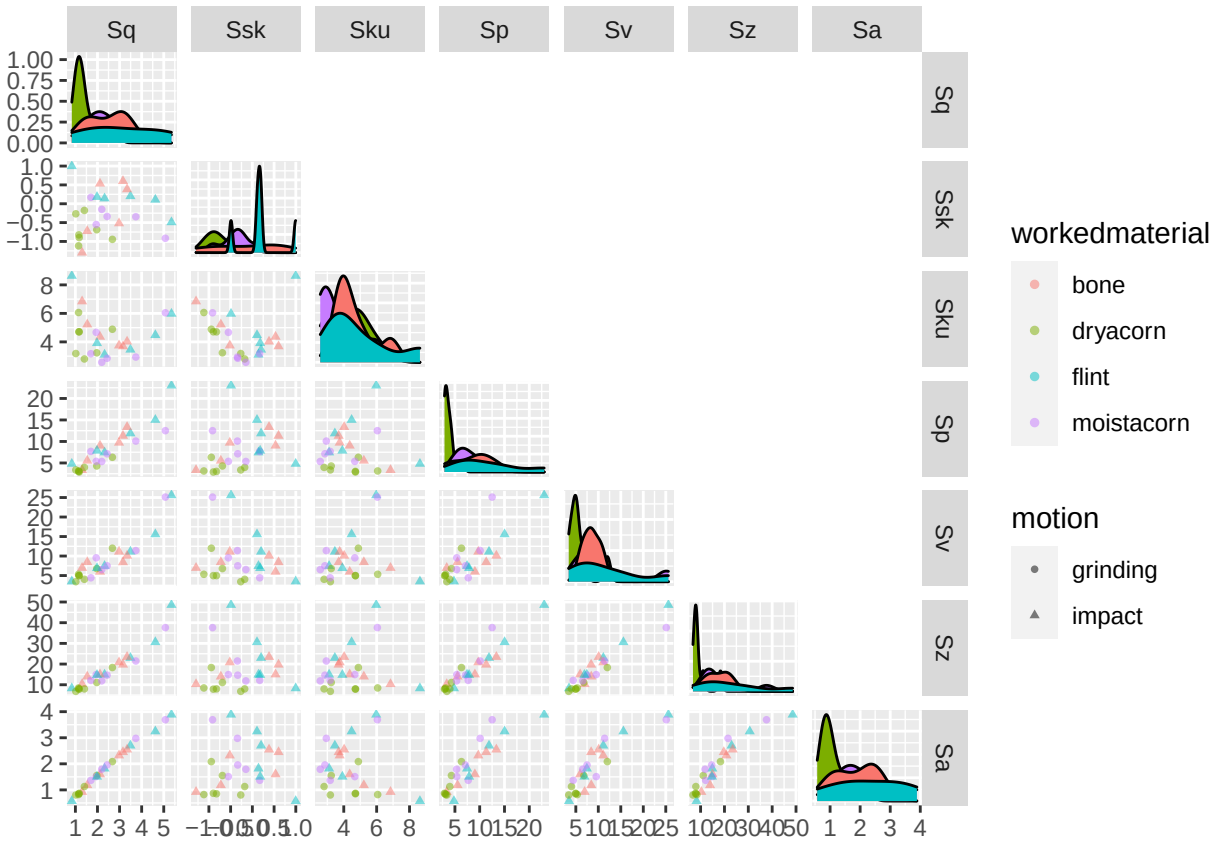
```
## Saving 6.5 x 4.5 in image
```

Scatterplot matrix for the ISO 25178 Area scale, Height and volume parameters

```
data(confocaldata, package = "reshape")
```

```
## Warning in data(confocaldata, package = "reshape"): data set 'confocaldata' not
## found
```

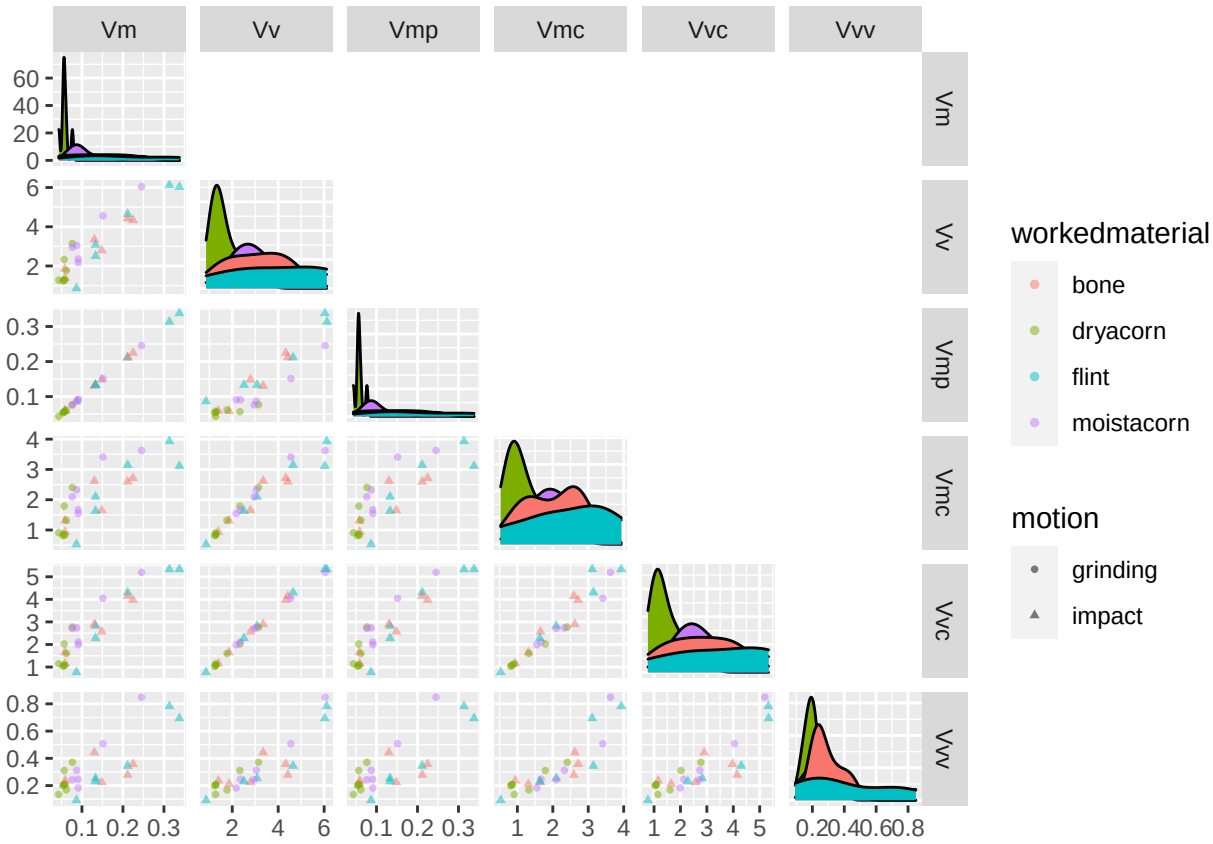
```
# Height parameters

ggpairs(data=confocaldata,
        columns = c(21:27),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial, shape = motion),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```




```
ggsave("../plots/confocalarea_matrix.png")
```

```
## Saving 6.5 x 4.5 in image
```

```
# Volume parameters

ggpairs(data=confocaldata,
        columns = c(36:41),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial, shape = motion),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```



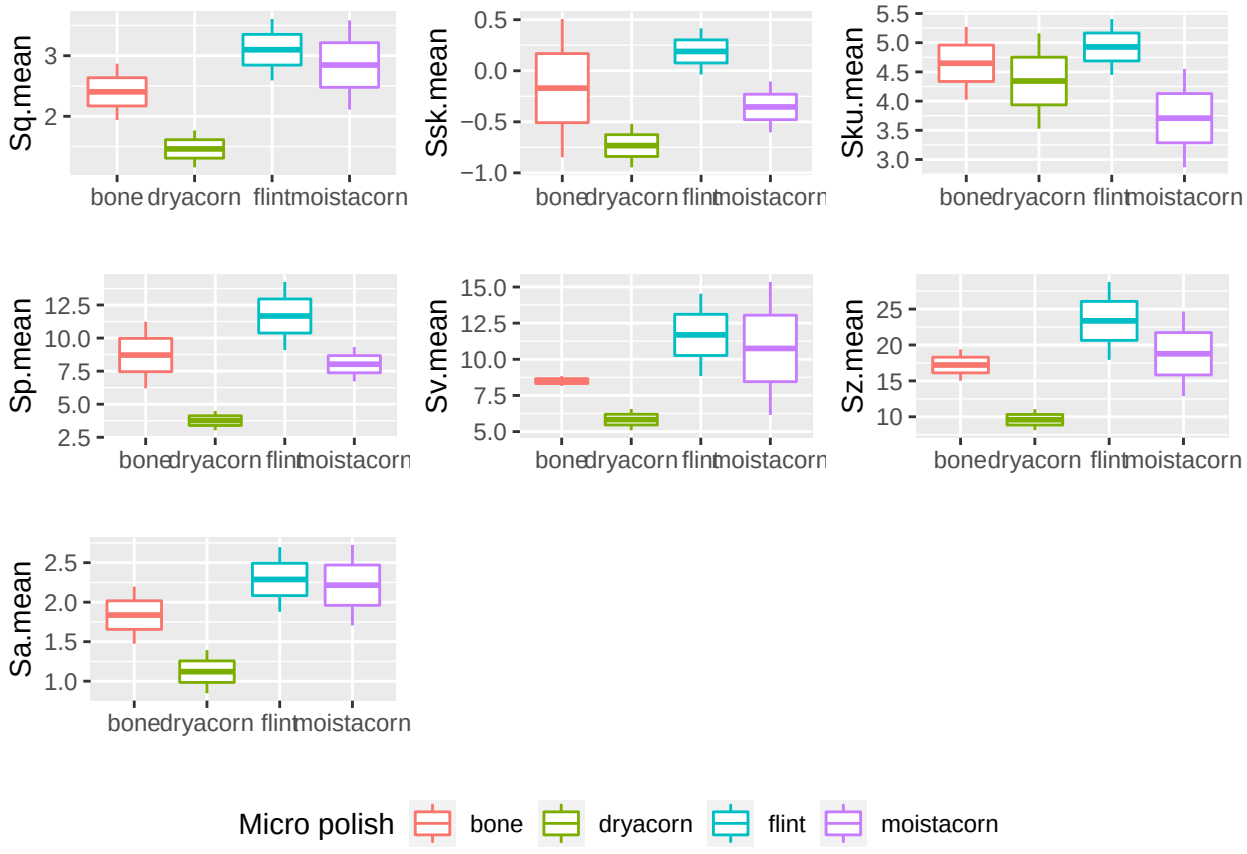

```
ggsave("../plots/confocalvolume_matrix.png")
```

```
## Saving 6.5 x 4.5 in image
```

Plot confostats for the ISO 25178 Area-scale, Height and volume parameters

```
# select parameter from dataset

# first Height parameters

heightconfostatsexp <- select(confostatsexp,sample,workedmaterial, Sq.mean,Ssk.mean,Sku.mean,Sp.mean,Sv

p1 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sq.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p2 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Ssk.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p3 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sku.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")
```

```
p4 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sp.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p5 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p6 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sz.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p7 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sa.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p1, p2, p3, p4, p5, p6, p7, common.legend = TRUE, font.label = list(size=8), legend="bottom")
```

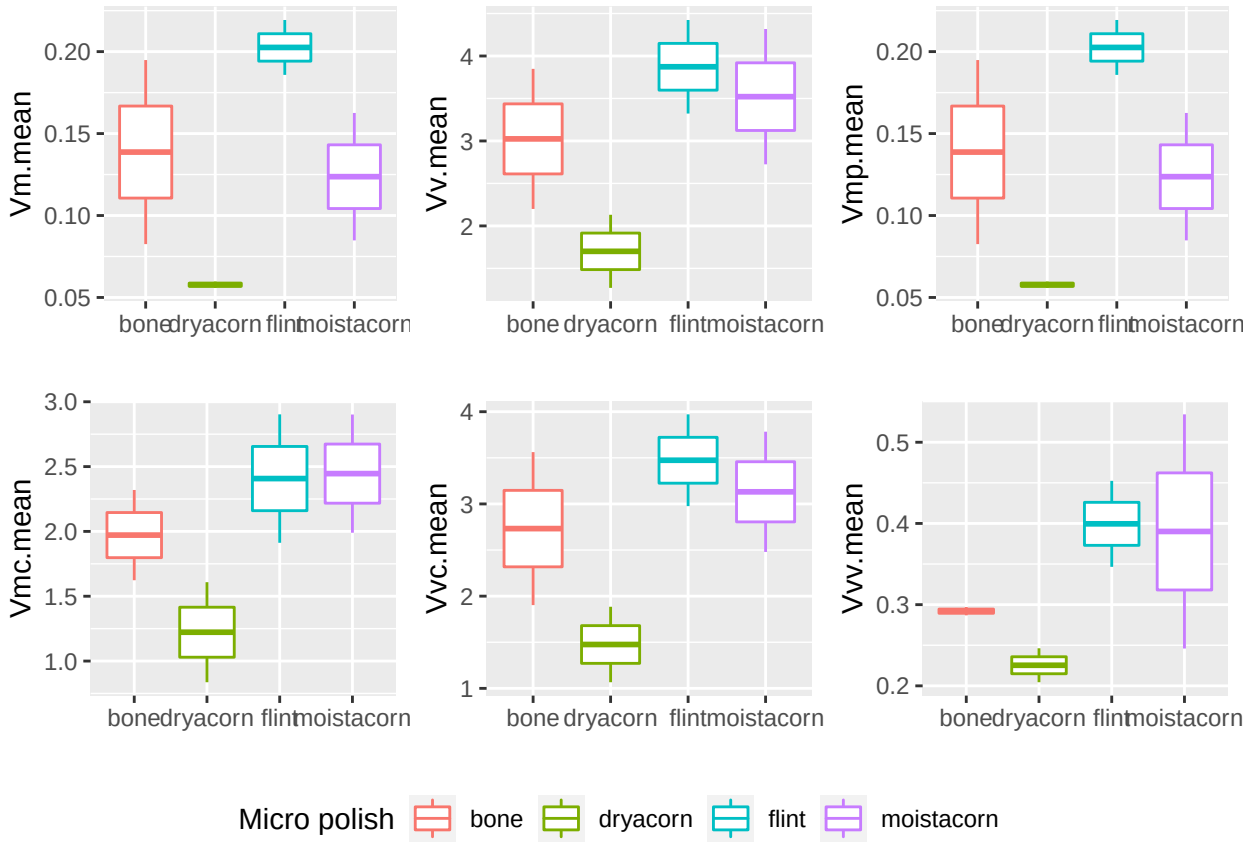



```
ggsave("../plots/confostatsarea_boxplots.png")
```

```
## Saving 6.5 x 4.5 in image
```

```
# Now, compute Volume parameters

volumeconfostatsexp <- select(confostatsexp,sample,workedmaterial, Vm.mean,Vv.mean,Vmp.mean,Vmc.mean,Vv
```

```
p8 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vm.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p9 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p10 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vmp.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p11 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vmc.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p12 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vvc.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p13 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vvv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p8, p9, p10, p11, p12, p13, common.legend = TRUE, font.label = list(size=8), legend="bottom")
```



```
ggsave("../plots/confostatsvolume_boxplots.png")
```

```
## Saving 6.5 x 4.5 in image
```

Show plot files information

```
info_out <- list.files(path = "derived_data", pattern = "\\.pdf$", full.names = TRUE) %>%
            md5sum()
```

End and Session info

```
sessionInfo()
```

```
## R version 4.0.4 (2021-02-15)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Catalina 10.15.7
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] tools     stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] ggfortify_0.4.11 ggpubr_0.4.0     doBy_4.6.8       GGally_2.1.0
##  [5] kableExtra_1.3.1 janitor_2.1.0    knitr_1.31       forcats_0.5.1
##  [9] stringr_1.4.0    dplyr_1.0.4      purrr_0.3.4      readr_1.4.0
## [13] tidyr_1.1.2      tibble_3.0.6     ggplot2_3.3.3    tidyverse_1.3.0
##
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2         jsonlite_1.7.2     viridisLite_0.3.0  carData_3.0-4
##  [5] modelr_0.1.8       assertthat_0.2.1   highr_0.8          cellranger_1.1.0
##  [9] yaml_2.2.1         pillar_1.4.7       backports_1.2.1    lattice_0.20-41
## [13] glue_1.4.2         digest_0.6.27      RColorBrewer_1.1-2 ggsignif_0.6.0
## [17] rvest_0.3.6        snakecase_0.11.0   colorspace_2.0-0   cowplot_1.1.1
## [21] htmltools_0.5.1.1  Matrix_1.3-2       plyr_1.8.6         pkgconfig_2.0.3
## [25] broom_0.7.4        haven_2.3.1        scales_1.1.1       webshot_0.5.2
## [29] openxlsx_4.2.3     rio_0.5.16         farver_2.0.3       generics_0.1.0
## [33] car_3.0-10         ellipsis_0.3.1     withr_2.4.1        cli_2.3.0
## [37] magrittr_2.0.1     crayon_1.4.0       readxl_1.3.1       evaluate_0.14
## [41] fs_1.5.0           MASS_7.3-53        rstatix_0.6.0      xml2_1.3.2
## [45] foreign_0.8-81     data.table_1.13.6  hms_1.0.0          lifecycle_0.2.0
```

```
## [49] munsell_0.5.0      reprex_1.0.0       zip_2.1.1          Deriv_4.1.2
## [53] compiler_4.0.4     rlang_0.4.10       grid_4.0.4         rstudioapi_0.13
## [57] labeling_0.4.2     rmarkdown_2.6      gtable_0.3.0       abind_1.4-5
## [61] DBI_1.1.1          reshape_0.8.8      curl_4.3           R6_2.5.0
## [65] gridExtra_2.3      lubridate_1.7.9.2  stringi_1.5.3      Rcpp_1.0.6
## [69] vctrs_0.3.6        dbplyr_2.1.0       tidyselect_1.1.0   xfun_0.20
```