## Wpksgtuks{ 'qhFkkudwt i j

# QTVJ QRCGF Æ 'TQDQVÆU NCDQTCVQT[

4238''uwo o gt''wpf gti tcf wcvg'' cduvtcev''dqqmgv







## HQTGY QTF

Vj g" Qtyj qr cgf ke" Tqdqvkeu" Ncdqtcvqt {" ku" yj g" Wpkxgtukx{" qh" Rkvudwti j øu" eqncdqtcvkxg" ghqtv' dgw ggp" yj g" F gr ctvo gpv" qh" Dkqgpi kpggtkpi " cpf " F gr ctvo gpv" qh" Qtyj qr cgf ke" Uvti gt {0' Vj g" o kukqp" qh" y g" QTN" ku" yj g" r tgxgpvkqp" qh" f gi gpgtcvkxg" lqkpv'f kugcug" d {" ko r tqxkpi "f kci pquvke." tgr ckt." cpf "tgj cdkrkxvkqp" r tqegf wtgu" hqt" o wuewnqungrgvcn" kplwtkgu'wukpi "uvvg/qh' y g/ctv'tqdqvke" vgej pqnqi {0' Vj g" QTN' y qwf "rkng" vq" eqo o gpf "y g" y qtm" qh" y g" wpf gti tcf wcvg" uvwf gpwu" f wtkpi " y g" uvvo o gt" qh" 42380' Uvwf gpwu" o cf g" uki pkhecpv" ko r cewi" kp" y g" uvwf {" qh" j cpf." uj qwrf gt." cpf "npgg" lqkpv" f kugcugu0' Vj g" y qtm" qh" qwt "uvwf gpwu." y kj " y g" j gr" qh" qwt "o gpvqtu." eqpvtkdwgu" i tgcvn{" vq" y g" y qtrf" qh" qh" qt y qr cgf ke" tgugctej 0

### Qwt 'vgco





**Ej t kı'Eqo q** Ercuu''qh''4239 Dkqgpi kpggtkpi Wpkxgtukx{ "qh''O kej ki cp



**T { cp'Drem** Ercuu'qh'423: Dkqgpi kpggtkpi Wpkxgtuks{ "qh'Rkvudwti j



Go kť 'Cpvj qp{ Encuu''qh''4239 O gej cplecn'Gpi kpggtkpi Wpkxgtukk{ ''qh''Rkwudwti j



**Rcvt lemlJ ci i gt v{** Encuu"qh'4239" Dkqgpi kpggtkpi " Wpkxgtukx{ "qh'Rkwudwti j



Lcenłg'Uej cwdng Encuu''qh'423: " Dkągpi kpggtkpi " Wpkxgtuks{ "qh'Rksudwti j



**Uco kniRcvgn** Ercuu''qh''423: Dkqgpi kpggtkpi Wpkxgtukv{ ''qh''Rkvudwti j

## Vcdrg'qh'eqpvgpvu

**30' Rt gf levlpi 'O gej cplecn Rt qr gt vlgu'y kj 'S wcpvksc vlsxg'Wint cuqwpf 'O gcuwt gu''** T { cp'Drcem'I gtcrf 'Hgttgt.'O cucj kq''[ quj kf c.''Xqmgt'O wucj n'Tkej ctf 'GOF gdunk'' *F gr ct vo gpv'qhDkqppi kpggt pi ''cpf ''F gr ct vo gpv'qhQt vj qr cgf ke''Uwt i gt {*  Rci g'7/8

- 40' Køhnegpeg'ahiDapg'O kogt criF gpuks{ '( 'Køugt vlap 'Vat s vg'ap 'CEN'Uahv'Vkuneg'I t chv'<sup>Rci g'9/:</sup>" Hæc vlap 'y køj 'Køvgt hgt gpeg'Uet gy u Ej tku'Eqo q. 'Gro ct'J gtduv.''Vj qo cu'Rhgkhngt.''Lcp/J gpf tkn'P cgpf twr.''Xamgt 'O wucj n" Tkej ctf 'G0F gdunk F gr ct vo gpv'ahiDkagpi koggt pi 'cpf'F gr ct vo gpv'ahiQt vj ar cgf ke 'Unt i gt {
- 50' Ko rcev'qh'Uetgy 'Ngpi vj 'qp'Hkzgf 'Rt qzko cnUecrj qkf 'Ht cewst g'Dkqo gej cpkeu<'Kp'<sup>Rci g'!/32</sup>" Xkst q'Uwsf { 'y kj 'Nqcf 'vq'Hckswt g'cpf 'E { enle'Nqcf kpi Uco km'Rcvgn'Lwcp'I kwi crg. 'P cy cp''Vkgf gngp. 'T qdgtv'Mcwho cpp. 'Lqj p'Hqy rgt." Tkej ctf 'G0F gdunk F gr ct vo gpv'qh'Dkqgpi kpggt kpi "cpf "F gr ct vo gpv'qh'Qt vj qr cgf ke "Uwt i gt {
- 60' S wcpvłłkecylop'lph'Egmwret ks{ 'cpf 'Nkr qkf 'F gi gpgt cylop' 'q'Curguu'Nqecnk gf '' F gi gpgt cylop 'Ip 'T qwc wqt 'E whłi Vgpf qpu Lees wgrkpg ''Uej cwdrg. 'T qdgt v'O 'O krrgt. 'X qrrgt 'O wucj n 'T kej ctf 'F gdunk

F gr ct vo gpv'qh'Dkqgpi kpggt kpi "cpf "F gr ct vo gpv'qh'Qt vj qr c gf ke "Uvt i gt {

70' Wikik kpi 'c'5F 'O qvkqp/Vt cemkpi 'U{ uvgo 'hqt 'vj g'Dkqo gej cplecnCpcn( uku'qh'F kuvcn<sup>Rci g'35/37</sup>" Vkdkqhkdwrct 'Mlpgo cvleu

Rcvtkem LOJ ci i gtv{."Vj qo cu'T0Rhgkhigt."Eqpqt"KOO wtrj {."Lqugrj "R0T wuugm "Tkej ctf 'G0 F gdunk 'O cecnwu "X0J qi cp F grctvo gpv'qhDkqgpi kpggtkpi "cpf "F grctvo gpv'qhQtyj qrcgf ke "Uwti gt {

#### Rt gf levlpi 'O gej cplecnRt qr gt vlgu'y ky 'S wcpvlscvlscg'Wint cuqwpf 'O gcuwt gu

Drcem'TV<sup>3</sup>='Hgttgt.'I C<sup>3</sup>='[ quj kf c.'O<sup>4</sup>='O wucj n'X<sup>4.3</sup>='F gdunk'TG<sup>3.4</sup> 30' F gr ctvo gpv'qh'Dkqgpi kpggtkpi .'Wpkxgtukx{ ''qh'Rkwudwti j .'RC.'Wpkgf ''Uvcvgu 40' F gr ctvo gpv'qh'Qtyj qr cgf ke''Uwti gt {.''Wpkxgtukx{ ''qh'Rkwudwti j .'RC.''Wpkgf ''Uvcvgu

**Kovt qf wevkqp**<'What cuqwpf 'ku'c'eqo o qp'ko ci kpi " o qf crkv{ "wugf "vq"gx cnvcvg"o wue wrqungrgvcn' vkuu wgu" pqp/kpxcukxgn{ "cpf 'f { pco kecm{ "]3\_0Vkuvg" i gqo gvt { "ecp"dg"cuuguugf "qdlgevkxgn{."dw" f gygto kokpi "\kuuwg"s workv{ "ku"noti gn{ "uwdlgevkxg0Cu"c" tguwn."enkplecn'wntcuqpqi tcr j { "gzco kpcvkqpu"j cxg" my "tgr gcvcdkkk/ "dgw ggp"gzco kpgtu"]3\_0Rtgxkqwu" uwuf kgu'j cxg'r tqr qugf 'y g'wug'qh's wcp kkc kxg'' wntcuqwpf "o gcuwtgu"\*S WU+"vq"qdlgevkxgn{ "gxcnwcvg" vkuuwg"s workv{ "wukpi "wnt cuqwpf "ko ci kpi "]3.6.7\_0"kp" cf f kkqp. 'uwf kgu'j cxg'uj qy p''y cv'dgwgt 'vgpf qp'' s works{ "ku'eqtt grovgf "y ky 'S WU'o gouwt gu'kpenst kpi " j ki j gt "xcnwgu"qh"gej qi gpkekv{ "cpf "xctkcpeg"cpf " ngy gt 'xcnwgu'qh'ungy pguu'cpf 'mwtvquku']6\_0' J qy gxgt. "y g"tgrcvkqpuj kr "dgw ggp" y gug SWU" o gcuwtgu'cpf 'o gej cpkecn'r tqr gtvkgu'qh' o wuewngungngvcn'vkuuwgu."y j kej "ctg"tgrtgugpvcvkxg"qh" vkuuwg''s workv{."ctg'r qqtn{ 'wpf gtuvqqf 0'Vj gtghqtg."vj g'' qdlgevkxg"qh"yj ku'uwwf { "ku"vq"t grcvg"o gej cpkecn" r tqr gt kgu''qh'j wo cp''ypf qp''y kj 'S WU'o gcuwtgu''yq'' dg"cdrg"'vq"s vcpvkh{ "vgpf qp"s vcrkv{ 0KV y cu" j {r qyj gukt gf "yj cv'j ki j "xcnwgu"qh"gej qi gpkekw{ "cpf " xctkcpeg"cpf "my "xcnwgu"qh"ungy pguu"cpf "mwtvquku" ctg'tgrcvgf 'vq'i tgcvgt'o gej cpkecn'r tqr gtvkgu'' tgrtgugpvkpi "dgwgt" vkuuwg"s workv{0

O gyj qf u<Hxg'htgij 'htq| gp"ecf cxgtke"npi 'j gcf 'qh" dkegr u'\gpf qp '\*NJ DV+'y gtg'j ctxguvgf 'htqo 'kpvcev'' uj qwf gt 'ur gelo gpu'\*7; 0 'Õ'; 08"{gctu'qrf +0'Vj g'' NJ DV'y cu'y gp 'f kuugevgf 'kpvq'c'öf qi /dqpgö'uj cr g'' cr r tqzko cvgn{ 'j ch'y g'y kf y ''qh'y g'\vgpf qp'\q''gpuvtg'' hcknvtg'kp''y g''o kf uwduvcpeg'']4.5\_0'Vy q'twddgt''dcpf '' o ctngtu'y gtg''uwr gti nvgf '\q''y g'\vgpf qp''cv'y g''gpf u'' qh'y g''of qi /dqpgö'tgi kqp''q''r tqxkf g''c''r qkpv'qh'' tghgtgpeg'\q''gpuvtg''tgr gcvcdkkv{ ''dgw ggp''wntcuqwpf '' ko ci gu'\*Hki 03+0'Wukpi ''c'ncugt''uecppgt '\*P gzv'Gpi kpg.'' F gumqr ''5F ''Lecppgt.''Lcpvc'O qpkec.''EC.''WUC+.''y g'' etquu/ugevkqpcn'ctgc''qh'y g''NJ DV'y cu'y gp" ugewtgf '\q''y g''o cvgtkcni'yguvkpi ''o cej kpg'\*Kputqp O qf gn7; 87. 'P qty qqf. 'O C. 'WUC+'hqt 'wpkczkcn' vgpukng'vguvkpi 'wukpi 'uqhv'vkuuwg''enco r uOC 'nc { gt ''qh'' umkp"y cu"y ter r gf "etqwpf "y g"\gpf qp"\q"emqy "hqt" wntcuqwpf "ko ci kpi "f wtkpi "o gej cpkech'vguvkpi 0" Hqt "o gej cpkech'ygukpi."c"3P "rtgrqcf "y cu"crr nkgf "yq" y g'NJ DV. hqmqy gf 'd{ 'r tgeqpf kkqpkpi 'htqo '3/32P '' hqt"42"e{engu"cv32"o o lo kp0Chygt"r tgeqpf kkqpkpi." y g'NJ DV'y cu'mcf gf 'htqo '3/52P 'hqt'72'e{engu'cv' 32"o o lo kp0Vj g"o cz"mcf "qh"c"mcf kpi "ugv'y cu'y gp" kpetgcugf "d{ "42P "wpvkn'vgpf qp'hcknwtg"qeewttgf "%kg0" 3/52P.''3/72P.''gve0+0Hqmqy kpi ''gcej ''nqcf kpi ''ugv.'' y tgg'wn tcuqwpf 'ko ci gu'<sup>sy</sup>I G. 'NQI KS 'U: .''Hckthkgrf .'' EV. "WUC+"y gtg"\cngp"cv"y g"o cz "mcf "qh"gcej " mcf kpi "ugv'd{ "c"ukpi mg"gzr gtkgpegf "wntcuqwpf " gzco kpgt"wukpi "c"tki "f guki pgf "vq"gpuwtg"tgr gcvcdrg" r ncego gpv'qh'y g'wnxtcuqwpf 'r tqdg0'Hqt"gcej " wntcuqwpf 'ko ci g."c"tgi kqp"qh'kpvgtguv'\*TQK+'y cu" ugngevgf "cu'c "dqz "egpvgtgf "dgw ggp" y g'twddgt "dcpf " o ctmgtu'\*Hki 03+0S WU'o gcuwtgu'\*Ungy pguu." Mwtvquku. "Xctkcpeg. 'Gej qi gpkekv{ +'y gtg"ecrewrcvgf " htqo "c"i tc{uecng"f kuxtkdwkqp"r tqf wegf "htqo "y g" TQK]3.6.7\_0S WU'o gcuwtgu'htqo "gcej "qh'y g'y tgg" wntcuqwpf "ko ci gu"\cngp"hqt"c"nqcf kpi "ugv"y gtg" cf lwuygf "\q"ceeqwpv'hqt "dcugnkpg'S WU'o gcuwtgu"qh" uwttqwpf kpi .'wpmcf gf 'licv'\kuuwg0O gej cpkecn



Hi wt g'3<V{r kecn'Wintcuqwpf 'ko ci gu'qh'NJ DV'qdvckpgf 0' Vj g'TQKhqt ''y g'NJ DV'ku'f ghkpgf ''d{ ''y g''{ gmqy ''dqz ''kp''y g'' ko ci gu0C+'Wintcuqwpf 'ko ci g''cv'37'O Rc''mecvgf ''y kj kp''y g'' vqg'tgi kqp''qh'y g''untguu''untckp''ewtxg0D+'WU'ko ci g''cv'4: 'O Rc'' mecvgf ''y kj kp''y g''hpgct'tgi kqp''qh'y g''untguu''untckp''ewtxg0

r tqr gtvkgu'kpenwf kpi 'vqg'tgi kqp'vcpi gpv'o qf wnwu'cpf " nkpgct"tgi kqp"vcpi gpv"o qf wnwu"y gtg"f gygto kpgf" wukpi "yj g"rcuv'e { eng"qh'yj g"uvtguu'uvtckp"ewtxg"hqt" gcej "nqcf kpi "ugv."y j kng"etggr "y cu"f gvgto kpgf "wukpi " y g'rcuv'cpf 'kpkkcn'e{ergu'qh'y g'utguu'utckp'ewtxg' hat "gcej "mgcf kpi "ugv0C"dcemy ctf u'o wnkr ng"rkpgct" tgi tguukqp"y cu'r gthqto gf "\q"\guv'y g"kphnwgpeg"qh" S WU'o gcuwtgu''qp''o gej cpkech'r tqr gtykgu''qh''y g'' vgpf qp0'Uki pkhkecpeg'y cu'ugv'cv'r '>'20270

**Tguwnu** C''uki pkhecpv'o wnkr ng'hkpgct''tgi tguukqp'' o qf gnly cu'hqwpf 'hqt "gcej "o gej cpkecn'r tqr gtv{" f gygto kpgf "kp"y ku'uwyf { "kpxqnxkpi "y g"kpygtcevkqp"qh" cv'rgcuv'w q'S WU'o gcuwtgu'cu'r tgf levqtu'\*Vcdrg'3+0' Dqy "etggr "cpf "hpgct"tgi hqp"\cpi gpv'o qf wnwu'y gtg" r tgf levgf "d{ "y g"kpvgtcevkqp"dgvy ggp"mvtvquku"cpf " xctkcpeg."y j kng"\qg"tgi kqp"\cpi gpv"o qf wnwu"y cu" r tgf levgf "d{ "vj g"løvgtcevlap"dgw ggp"ungy pguu." mwtvquku."cpf "xctkcpeg0Vj g"uki p"qh"vj g"dgvc" eqghhlelgpv'lof lecvgu'y g'v(rg''qh'tgrcvlqpu kr'' dgw ggp''y g''xctkcdngu'\*kg0'r qukkxg''ku''f ktgev'' tgrcvkqpuj kr."pgi cvkxg"ku"kpxgtug"tgrcvkqpuj kr+0"Hqt" gzco r ng. "etggr "y cu'hqwpf "vq"dg"kpxgtugn{ " r tqr qt kqpcn' vq "mxt vquku"cpf "xctkcpeg" \* Etggr "? "\*/" 8043+\*Mwtvquku+"- "\*/2027+\*Xctkcpeg+"- "480; : +."vj wu" f getgcukpi "mwtvquku"cpf "xctkcpeg"y gtg"tgrcvgf "vq" kpetgcukpi "etggr 0"Vj gtg"y gtg"pq"qvj gt"uki pkhecpv" o wnkr ng'nkpgct'tgi tguukqp'o qf gnu'dgw ggp'y g" o gej cpkecn'r tqr gtvkgu'\*Etggr . "Vqg'Tgi kqp''Vcpi gpv' O qf wnwu."Nkpgct 'T gi kqp 'Vcpi gpv'O qf wnwu+"cpf ''y g'' S WU'o gcuwt gu'\*Ungy pguu. "Mwt vquku. "Xct kcpeg." Gej qi gpkekx{+0

F knewnukqp<Rtgxkqwu'uwwf kgu'j cxg'uj qy p''y cv' f khigt gpv'o gcuwt gu''qh''kuuwg''s wcrkv{ "kpf kx kf wcm{ " eqttgrcvg'y ky "ukpi rg'S WU'o gcuwtgu']6\_Wj g'tguwnu" qh'y ku'uwf { "uj qy "y cv'y g'kpygtceykqp"qh'o wnkr ng" S WU'o gcuwtgu'ecp''r tgf kev'o gej cpkecn'r tqr gtvkgu." tgrtgugpvcvkxg"qh'vkuuvg"s vcrkv{0Dqvj "etggr"cpf"

nkpgct"tgi kqp"\cpi gpv'o qf wnwu'y gtg"uj qy p"\q"dg" kpxgtugn{ 'tgrcvgf '\q'mvtvquku'cpf 'xctkcpeg.'y j krg'\qg'' tgi kqp"\cpi gpv"o qf wnwu"y cu"uj qy p"\q"dg"f ktgevn{" tgrcvgf "vq"ungy pguu"cpf "kpxgtugn{"tgrcvgf "vq"mvtvquku" cpf 'xctkcpeg0'Vj gug'tguwnu'f q'pqv'uwr r qtv'qwt" kpkkcn'i {r qy guku.'i qy gxgt'y g'kpygtcevkqp'dgw ggp'' o wnkr ng'S WU'o gcuwtgu''cu''r tgf kevqtu''qh'o gej cpkecn'' r tar gtvkgu'kphnvgpegu'vj g'tgrcvkapuj kru'adugtxgf" dgw ggp"y g'S WU'o gcuwtgu"cpf "o gej cpkecn" r tqr gt vkgu01kp''y g'hwwtg."qy gt 'o wuewnqungngvch' vkuuwgu."kpenxf kpi 'tqvcvqt"ewhh'vgpf qpu."y km'dg" cuuguugf "wukpi 'S WU'o gcuwtgu"\q"f gygto kpg"\kuuwg" s workv{ 0Vj gug'S WU'o gcuwt gu'y km'r tqxkf g" enkpkekcpu'y ky 'c'tgr gcvcdrg'\qqn'\q'r tgf kev' o gej cpkech'r tqr gtvkgu''qh''o wuewnqungngvch'\kuuwg'' wukpi 'wntcuqpqi tcrj {.'r tqxkf kpi 'kpuki j v'qp'\kuuwg'' s worky{ "cpf "o ketquvt we witg0

Ui pl/lecpeg<En/plekcpu'y km'dg"cdrg''vq "wug"S WU" o gcuwtgu'vq 'dgwgt 'cuuguu'o gej cpkecn'r tqr gt vkgu'qh' o wuewnqungngvcnl\kuuwg."tgrtgugpvcvkxg"qhl\kuuwg" s wcrkv{."y ky "wntcuqpqi tcr j {."c"eqo o qp." kpgzr gpukxg."cpf "f { pco ke"ko ci kpi "o qf crkv{."vq" kortqxg"vtgcvogpvu0

Tghgt gpegu<']3\_'Eqmkpi gt''L'gv''cn0Cecf go ke'' Tcf kqmji {0422; ="38-3646/36540"]4 "O eI qwi j "T"gv" cn0Mpgg"Uvti."Ur qtvu"Vtcvo qvqn"Ctyj tqueqr {0 3; ; 8=5448/44; "15 "Mant 'E "gv"cm)Enkplecn" Dkqo gej cpkeu04237='52< 62/; 670']6\_'Eqmkpi gt'L'gv' cn0Co 0L0Rj {u0O gf 0T gj cdkr04232=":; 5; 2/6220 ]7\_'Eqmkpi gt''L'gv'cn0RO ''T04232=''4<, 42/; 470

	Creep (9	Vcdrg'3<				
Predictors	Beta Coefficients	Intercept	R <sup>2</sup>	Uwo o ct { "qh"		
Kurtosis	-6.21	26.98	0.595	ownwkrng"nkpgct" tgitguukap"cpcn{uku"		
Variance	-0.05			r gthqto gf		
Το	e Region Tange	dgw ggp'S WU				
Predictors	Beta Coefficients	Intercept	R <sup>2</sup>	o gcuwtgu'cpf "		
Skewness	458.68	529.42	0.540	o gej cpiech		
Kurtosis	-235.74			r tqr gt vkgu0		
Variance	-0.55					
Line	ear Region Tang	ent Modulus				
Predictors	Beta Coefficients	Intercept	R <sup>2</sup>			
Kurtosis	-105.38	852.95	852.95	05.38 852.95 0.30	0.309	
Variance	-0.53					

#### Kohwegpeg'qhiDqpg'O kpgt criF gpuks{ '( 'Kougt vkqp'Vqt s wg'qp'CEN'Uqhr'Vkuuwg'I t chr'Hkz cvkqp'y ky " Kovegt kg t gpeg'Uet gy u

Ej tku'LO'Eqo q<sup>3</sup>. 'Gro ct'J gtduv<sup>3</sup>. 'Vj qo cu'Rhgkhhgt<sup>3</sup>. 'Lcp/J gpf tkn'P cgpf twr<sup>3</sup>. 'Xqmgt'O wucj n<sup>3</sup>. 'Thej ctf 'GO'F gdunk<sup>3</sup>

<sup>3</sup>Qtyj qr cgf ke'Tqdqvkeu'Ncdqtcvqt {. "Wpkxgtukv{ "qh"Rkvudwti j. "Rkvudwti j. "RC

 $\label{eq:constraint} F \mbox{ kuenquwtgu} Ej \mbox{ tku'L0} Eqo \ q'``P + 'Gro \ ct'J \ gt \mbox{ duv}``P + 'Vj \ qo \ cu'Rhgkhigt'``P + 'Lcp'J \ gpf \ tkn'P \ cgpf \ twr '``P + 'Xqmgt'' O \ wcj \ n``P + 'Tkej \ ctf 'G0F \ g\ dunk'``P + 'Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + 'Xqmgt'' \ O \ wcj \ n``P + 'Tkej \ ctf 'G0F \ g\ dunk'``P + 'Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + 'Xqmgt'' \ O \ wcj \ n``P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + ''Xqmgt'' \ O \ wcj \ n``P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + ''Xqmgt'' \ O \ wcj \ n``P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + ''Xqmgt'' \ O \ wcj \ n``P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + ''Xqmgt'' \ O \ wcj \ n``P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + ''Xqmgt'' \ o \ wcj \ n``P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + ''Xqmgt'' \ o \ wcj \ n``P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '``P + ''Xqmgt'' \ o \ n'`P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '`P + ''Xqmgt'' \ o \ n''P \ cgpf \ twr '`P + ''Lcp''J \ gpf \ tkn'P \ cgpf \ twr '`P + ''Yqmgt'' \ cgpf \ twr '`P + ''Yqmgt'' \ cgpf \ twr '`P + ''Yqmgt'' \ cgpf \ twr '`P + ''P \ cgpf \ twr '`P \ twr '`P + ''Yqmgt'' \ cgpf \ twr '`P \ tw$ 

Kpvt qf wevkqp<" F wg" vq" yj g" kpetgcugf " cyj ngvke" r ctvkekr cvkqp" qh" o kf f ng/ci gf " cpf " gnf gtn{ " r gqr ng." o qtg"ur qtvu"tgncvgf "kplwtkgu"j cxg"qeewttgf "hqt"y gug" ci g" i tqwr u0' Y j gp" r gthqto kpi " uwti gt { " qp" y gug" r cvkgpvu." uwti gqpu" o wuv" eqpukf gt" c" r quukdn{" f getgcugf " dqpg" o kpgtcn' f gpukx{" \*DO F +" ]3\_0' Hqmqy kpi " cpvgtkqt " etwekcvg" nki co gpv" \*CEN+" tgeqput wevkqp'r tqegf wtgu. "y g'i tchv'hkzcvkqp'uvtgpi y " pggf u'vq'y ky uvcpf "hqtegu"f wtkpi "r j { ukech'y gtcr { "cu" y gm'cu'uxtgpwqwu''cevkxkkgu''qpeg''y g''r cvkgpv'tgwtpu'' vq" ur qt vu" dgec wug" yj g" i tchv" ku" pqv" {gv" hwm{" kpeqtrqtcvgf" ]4\_0' Rctvkewnctn{" y j gp" wukpi" kpvgthgtgpeg" uetgy u." yjg" i tchv" hkzcvkqp" uvtgpi yj" f gr gpf u"qp"dqpg"o kpgtcn'f gpukv{ "qh'y g"uwdlgevu"cpf " kpugtvkqp" vqts wg" qh" yj g" kpvgthgtgpeg" uetgy "]5."6\_0' J qy gxgt."y g"kphrwgpeg"qh'f khgtgpv'uetgy "uk gu"j cu" pqv'dggp"gzco kpgf0'Vj gtghqtg."yj g"r wtr qug"qh"yj ku" uwaf { " y cu" vq" kpxguvki cvg" vj g" kphnvgpeg" qh" dqpg" o kpgtcn'' f gpukv{ "cpf " kpugt vkqp" vqts wg" qp" rqcf/vq/" hcknwtg"cpf "uvkhpguu"qh" w q"kpvgthgtgpeg" uetgy u"hqt" CEN'uqhv'\kuuvg'i tchv'hkzcvkqp0'Dcugf "qp'r tkqt''uvwf kgu" y cv" kpxguvki cvgf " y g" uetgy " i gqo gvt { " ]7\_." kv" y cu" j {r qy guk gf "y cv'qxgtuk kpi "y g"kpvgthgtgpeg"uetgy " d{" qpg" o kmko gygt" tgrcykxg" yq" yj g" dqpg" wppgn" f kco gygt"y km"tguwn/"kp"c"j ki j gt"mcf/vq/hcknwtg"cpf" uvkhpguu'eqo r ctgf 'vq'cp'kpvgthgtgpeg'uetgy 'o cvej kpi " y g'dqpg'wppgn'f kco gvgt0

O gyj qf u<' Hqwtvggp" htguj /htq| gp" ecf cxgtke" mpggu" \*o gcp"ci g'7408"- 1/'3408"{tu+'y gtg"tcpf qo n{"cuuki pgf" vq"qpg"qh"vj g"hqmqy kpi "uetgy "eqpf kkqpu<'3+"uk gf" kpvgthgtgpeg" uetgy " o cvej kpi " vj g" dqpg" wppgn" cpf " itchv" fkco gvgt." 4+" qpg" okmko gvgt" qxgtukt gf" kpvgthgtgpeg"uetgy "eqo r ctgf "vq"vj g"dqpg"wppgn"cpf " i tchv'f kco gvgt0'Cm'kpvgthgtgpeg"uetgy u"j cf "c"ngpi yj " qh"w gpv{/hkxg"o kmko gvgtu0'Vq"f gvgto kpg"y g"DOF" qh'gcej 'ur geko gp. 'FZC'uecpu'\*I G'J gcny ectg'Nwpct" kFZC"Ocfkuqp."Y K4"qh"y g"ncvgtcn"hgo qtcn"eqpf {ng" y gtg"r gthqto gf 0'C"dqpg"uqengv"y kj kp"y g"pcvkxg" CEN'hqqvrtkpv'y cu'f tkngf 'ceeqtf kpi 'vq'y g'uk g'qh'y g'' i tchv"vq"c"f gr yj "qh"wy gpv{/hxg"o kmko gwgtu."cpf "yj g" s wcf twr ngf "cwqnqi qwu'j co uvtkpi "vgpf qp'i tchw'y gtg" kpugt vgf 0°C "vqts wg"uetgy f tkxgt "\*204 "P/o "ó"607 "P/o +" tgeqtf gf "vj g"kpugtvkqp"vqts vg0"Vj g"dqpg"y cu"r qvgf "kp" gr qz { " r ww{ " cpf " o qwpvgf " vq" c" o cvgtkcnu" vguvkpi " o cej kpg" \*KpuxtqpÌ "7; 87" F wcn' Eqnwo p" Vguvkpi " U{uvgo +0'Vj g'\kdkcn'gpf "qh'yj g'i tchv'y cu'enco r gf "cv'c" f kuvcpeg"qh'y tgg"egpvko gvgtu"htqo "y g"hgo qtcn'wppgn" cr gtwtg"vq"uko wncvg"yj g"kpvtc/ctvkewnct"i tchv'ngpi yj 0' Vj g"npi kwf kpcn'czku"qh" y g"dqpg" wppgn'y cu" y gp" crki pgf "vq"vj g"cr r rkgf "hqteg0

Ur geko gpu"y gtg"r tgmcf gf "y kj "32"P ."hqmqy gf " d{ "42"e{engu"qh"r tgeqpf kkqpkpi "dgw ggp"32"cpf "72" P 0'E {enke"etggr 'y cu'r gthqto gf "dgw ggp"32"cpf "472" P '\q'tgr nkecvg"hqtegu'kp"y g'CEN'i tch/f wtkpi 'y cmkpi " ]8\_0'Nqcf/vq/hcknwtg"vgukpi "cv'42"o o lo kp"y cu"y gp" r gthqto gf 0' Nqcf/vq/hcknwtg" cpf " uvkhpguu" y gtg" tgeqtf gf 0'C"eqttgncvkqp"cpcn{uku"hqt"gcej "i tqwr "y cu" r gthqto gf 'y ky 'y g'Rgctuqp"eqttgncvkqp"eqghhekgpv'vq" gxcnwcvg"y g"eqttgncvkqp"qh'dqy "kpugtvkqp"vqts wg"cpf " dqpg" o kpgtcn'f gpukv{ "y kj "y g" o czko wo " mcf/vq/" hcknwtg0'C"uwwf gpvou"v/vguv"y cu"wugf "vq"eqo r ctg"y g" tguwnu" dgwy ggp" yj g" w q" i tqwr u0' Vj g" uki pkhkecpeg" ngxgn'y cu'ugv'cv'r '>'20270

**Tguww** C" uki pkhecpv' eqttgrcvkqp" dgw ggp" dqpg" o kpgtcn'f gpukv{ "cpf "mcf/vq/hcknvtg"\*T"? "20992."r "? " 20265+'y cu'hqwpf 'hqt 'y g'uk gf 'uetgy 'eqpf kkqp.'uwej " y cv'j ki j gt"dqpg" o kpgtcn'f gpukv{ "eqttgur qpf gf "vq" j ki j gt"nqcf/vq/hcknwtg0'C"uvtqpi ."dwv"pqv"uki pkhecpv" eqttgrcvkqp"y cu"hqwpf "hqt"y g"qxgtuk gf "uetgy "\*T"?" 208: 4."r"?"20426+"\*Hki wtg"3+0'C"utqpi "eqttgrcvkqp" dgw ggp'kpugtvkqp'vqts wg"cpf "mcf/vq/hcknwtg'hqt"dqyj " y g'uk gf 'uetgy "eqpf kkqp'\*T"? '20 33."r "? '20249+"cpf " y g"qxgtuk gf "uetgy "eqpf kkqp"\*T"? "20744."r "? "2044; +" y cu"hqwpf 0'Utqpi ."dwi'pqv"uki pkhecpv"eqttgrcvkqpu" y gtg"hqwpf "dgw ggp"kpugtvkqp"vqts wg"cpf "uvkhpguu"hqt" dqy "uk gf "\*T"?"20876."r"?"20833+"cpf "qxgtuk gf " uetgy u"\*T"?"2073; ."r"?"20455+0'Dgw ggp"y g"w q" i tqwr u." qpn{" kpugt kqp" vqts wg" y cu" hqwpf " vq" dg" uki pkhecpvn{ "f khhgtgpv<sup>1</sup>\*r "? "20234+."y j gtgcu"DO F "\*r " ? "2089; +."mcf/vq/hcknwtg"\*r "? "204: 8+."cpf "uvkhpguu"\*r " ?"205;9+"f kf "pqv"f kthgt" uki pktkecpvn{"dgw ggp" yj g" uk gf "cpf "qxgtuk gf "uetgy "eqpf kkqpu"\*Vcdng"3+0

F kuewuukape Vj g'o quv'ko r qt vcpv'hkpf kpi "qh'yj ku'uwf {" ku'y cv'dqy "dqpg"o kpgtcn'f gpukv{ "cpf "kpugtvkqp"vqts wg" uxtqpi n{ "eqttgrcvg"y kj "rqcf/vq/hcknvtg"cpf "uvkhpguu" qh'CEN'uqhv'vkuuvg'i tchv'hkzcvkqp0'Y g'cnuq'hqwpf 'y cv' m\_cf/vq/hcknwtg" f gr gpf u" mguu" qp" DOF " hqt" y g" qxgtuk gf "uetgy "eqpf kkqp." rkngn{"f wg "vq "y g" qxgtuwhhipi "qh'y g'i tchv'cpf "uetgy "kp"y g"dqpg"wppgn" Gxgp"y qwi j "mcf/vq/hcknwtg"cpf "uvkhhpguu"y gtg"hqwpf" vq"dg"j ki j gt"kp" vj g"qxgtukt gf "uetgy "eqpf kkkqp."pq" uki pkhlecpv'f khlgtgpeg'y cu'hqwpf.'r ctvkcm( 'f kur tqxkpi " qwt"j {rqyj guku0'Kk"j cu"rtgxkqwun{"dggp"uj qy p"yj cv" kpugtvkqp"vqtsvg"eqttgrcvgu"rqukkxgn{"ykj"rqcf/vq/" hcknwtg"cpf "uvkhpguu0'J qy gxgt."wpvkn'pqy "uwti gqpu" eqwrf "pqv"s wcpvkh{ "yj g"kpugtvkqp"vqts wg"cpf "tgrkgf "qp" yjgkt" uwdlgevkxg" hggnkpi "fwtkpi "kpugtvkqp" qh" kpvgthgtgpeg"uetgy u0'Wukpi "c"vqts wg"uetgy ftkxgt"vq" f gygto kpg"kpugtykqp"vqts wg"o c{"j grr "vq"r tqxkf g"cp"

qdlgevkxg"o gyj qf "hqt"uwti gqpu"vq"f gvgto kpg"r tqr gt" hkzcvkqp" cpf "vq" kpvgtr tgv" yj g" i tchv" hkzcvkqp" kpvtcqr gtcvkxgn{"cpf "o qf kh{ 'vj ku"hqt"cpqvj gt "hkzcvkqp" o gyj qf 0'Vq"hwm{ "wpf gtuvcpf "vj g"kphnvgpeg"qh"DO F " qp"CEN"uqhv'vkuuvg"i tchv'hkzcvkqp."cf f kkqpcnihkzcvkqp" f gxkegu" \*kQg0" gz vtc/eqt vkecn" uwur gpuqt {" hkzcvkqp" vgej pks wgu+"pggf "vq"dg"kpxguvki cvgf 0

**Ui phłecpeg**<"Vj g"tguwnu"qh"yj ku"uwwf { "y km'r tqxkf g" uwti gqpu"y kyj "wughwh"kphqto cvkqp"vq"j gm "f gvgto kpg" yj g" qr vko cn" hkzcvkqp" vgej pks vg" hqt" cp" CEN" tgeqpuvtwevkqp"dcugf "qp"dqpg"o kpgtcn"f gpuks{ "cpf" kpugtvkqp" vqts vg0' Qxgtuk gf" kpvgthgtgpeg" uetgy u" r tqf veg"c"j ki j gt"mcf/vq/hcknwtg"cpf "uvkhhpguu"yi cp" uk gf" uetgy u." y j kej " o c { "r tqxg" vq" dg" vughwn" kp" vtgcvkpi "r cvkgpvu"y kyj "r ctvkewrctn{ "nqy "dqpg"o kpgtcn" f gpukskgu0

#### Tghgt gpegı≺

]3\_" Exklgvk ." Ugno c." O ktmq" Mqt-k 0' *Quvgqrqtquku*" *Kpvgtpcvkqpcn*' 4226=" ]4\_" O Ãpf gto cpp" C." gv' cn0' *L*" *Qt vj qr 'Tgu*'4237="]5\_"I cmq'TC."gv'cn0'*Mpgg*'4237="]6\_" Dtcpf "IE."gv'cn0'Co "L''Ur qt wi'O gf "4222="]7\_"Y gkrgt" C."gv'cn0'Co "L''Ur qt wi'O gf "4222="]8\_"Uj grdwtpg"MD." gv'cn0'L'Dkqo gej '4226

Table 1: Bone mineral density (BMD), insertion torque, load-to-failure, and stiffness for sized and oversized screws (mean  $\pm$  SD; \*p < 0.05)

Specimen	BMD (g/cm <sup>2</sup> )	Torque (N-m)	Load-to- Failure (N)	Stiffness (N/mm)
Sized	$1.178 \pm 0.324$	$1.4 \pm 0.4*$	$410.6 \pm 151.0$	$111.6 \pm 40.2$
Oversized	1.234 ± 0.097	$2.3 \pm 0.7*$	506.2 ± 168.8	133.0 ± 50.4
700				
600		R <sup>2</sup> =0.46571		
2 500 P		• •		
og 400			•	
E 300	R <sup>2</sup> =0.59253	and the second		
.E	and the second second	•	<ul> <li>Sized</li> </ul>	
ARM 200	•		Oversized	
100				
0				
0.4	0.6 0.8 Bone Minera	1 Density (g/c	2 1.4 1.6 m <sup>2</sup> )	

Figure 1: Correlation of BMD to maximum load for screw conditions

### Korcev'qh'Uetgy 'Ngpi vj 'qp'Hlzgf 'Rtqzkocn'Uecrj qlf 'Htcevwtg'Dkqogej cpkeu Ko'Xkstq'Uwf { 'y kyj 'E { enke'Nqcf kpi 'cpf 'Nqcf 'vq'Hcknwtg

Uco kniRcvgn 'Lvcp'I kvi cng'OF. 'P cy cp''Vkgf gngp'OF. 'T kej ctf 'G0F gdunk'Rj F. 'T qdgt v'Mcwho cp'OF. 'Lqj p'Hqy ngt 'OF

Qtyj qr cgf ke 'Tqdqvkeu'Ncdqtcvqt {. 'F gr ct vo gpv'qh'Dkqgpi kpggtkpi . 'Wpkxgtukv{ "qh'Rkvudwti j . 'RC. 'WUC

Kpvt qf wevkqp<' Kpvgtpcn' hkzcvkqp'' wugf'' cu'' vtgcvo gpv'' hqt'' uecr j qkf "htcewtgu" j cu" kpetgcugf " y kj " cf xcpegu" kp" uwti kecn" vgej pls wgu" ]3\_0' Rtqzko cn' r qng" uecr j qkf " htcewtgu" r tgugpv' c" enkpkecn' ej cmgpi g" f wg" vq" vj gkt" ny gt" uweeguu" tcvg" y j gp" ecuv" ko o qdktki cvkqp" cpf " kpvgtpcn" hkzcvkqp" ctg" wktki gf " ]4\_0" Uetgy u o czko k kpi ngpi y j cxg dggp uj qy p vq korcev y tkuv' o qvkqp" hqt" hkzgf" uecrjqkf" y ckuv' htcewstgu" ]5\_0' Cffkkqpcm{." uetgy u" y kj " i tgcvgt" f kco gvgtu" cpf " xct {kpi " igqogvt{" jcxg" dggp" ujqyp" vq" korcev" uvkhhpguu" cpf" wnko cvg" nqcf " cv' y g" htcewtg" ukg" hqt" hkzgf " uecr j qkf " y ckuv" htcewstgu0' Ewttgpvn{." y g" ghhgev' qh" uetgy " ngpi y " qp" y g" uxtwewtch' r tqr gtvkgu'' qh'' hkzgf " r tqzko ch' uecr j qkf " htcewtgu'' ku" pqv" y gm" wpf gtuvqqf" gxgp" y qwij" hkzcvkqp" qh" r tqzko cn" uecrj qkf " htcewstgu" j cu" c" j ki j " pqpwpkqp" tcvg0' Vj gtghqtg." y g" qdlgevkxg" qh" y ku" uwuf {" ku" vq" f gvgto kpg" y g" dgpf kpi " uvkhhpguu" cpf "wn ko cvg" nqcf "hqt" y g" nqcf kpi "qh" hkzgf " rtqzko cnuecrj qkf "htcewtgu"hqt"uetgy u"qh'xctkqwu'hgpi yj u0

**O gvj qf u**<' Hknggp." htguj " htql gp" ecf cxgtke" uecr j qkf u" \*7908Õ8205" {gctu" qh" ci g+" wpf gty gpv" cp" qdrks wg" quwgq qo {" y kj " c" (740 o " drcf g" ucy " vq" uko wrcvg" c" 90 o " r tqzko cn" qdrks wg" htcewt g" y kj " tgur gev" vq" yj g" rqpi " czku0' Gcej " uecr j qkf " y cu" tcpf qo n{" cuuki pgf " hqt " hzcvkqp" vq" qpg" qh" 5" r quukdrg" uetgy " rgpi yj u" \*p? 7+" qh" c" 4070 o " f kco gygt" egpvtcrl y tgcf rguu" uetgy " \*Ut { rgt. " Mcreo c| qq." O K" WUC +<' 320 o ." 3: o o ." cpf " 460 o " rgpi yj 0' Vj g" f kucn'r qrg" qh" y g" uecr j qkf u" y cu" r qwgf " kp" gr qz {" r wv{" \*Dqpf q." Uv0' Rcwn" O P." WUC +'' y kj " y g" uecr j qkf " mpi " czku" r gtr gpf kewrtt" vq" y g" j qtk qpvcn'r rcpg0' Vj g" uecr j qkf " y cu" yj gp" qtkgpvgf " cv" 67Å' vq" uko wrcvg" enkplecn' f qtucn'' vq" xqrct" dgpf kpi " rqcf " \*Hki wg"

3+0

Gcej "ur geko gp" y cu"e{enlecm{"nqcf gf "hqt" 3222"e{engu" y ky " cp": 22P o o " dgpf kpi " o qo gpv." y j gtg" y g" cr r nlgf " mqcf " \*6202P/8809P +" f gr gpf gf " qp" y g" o qo gpv" cto " dgw ggp" y g" r qwkpi " cpf " c" r nwpi gt" f tlxgp" d{" c" o cvgt kcm" vgu kpi " o cej kpg" \*Kpuxt qp." Gf gp" Rtckt kg." O P +0' Ukhthpguu" y cu" ecnewncyff " cv" y g" 3222 y e{eng" cpf " e{enle" hcknwtg" y cu" f ghkpgf " cu" gkaj gt " r nwpi gt " gz vgpuk qp " i tgcvgt" y cp" 407 o o " qt" c" r tqz ko cn'r qng" etceni kp" y g" eqpuxt wev" ]6\_0' Gcej " ur geko gp" y cu" mqcf gf " vq" hcknwtg" chwgt " e{enle" mqcf kpi 0' Hcknwtg" y cu" kpf kecvgf " d{" nuu" qh" htcewstg" tgf we kqp" qt " c" r tqz ko cn' etcemi kp" y g" eqpuxt wev' cu" c" tguwni' qh" mqcf kpi "\*Hki wtg" 4 ==' y ku" y cu" f ghkpgf " d{ " cu" c" f kn<br/>kpev" f getgcug" kp" y g" mcf/f kur mego gpv" ewtxg0

 $\bar{Q}pg/yc{" cpcn{uku" qh' xctkcpeg" *CPQXC+" vguvu" ygtg" r gthqto gf " vq" gxcnvcvg" f khgtgpegu" kp" uvkhpguu" cpf " nqcf " vq" hcknvtg0Uki pkhecpeg" ycu"ugv'cv'r>20270$ 

**Tguwuk'** P q" uki pkłkecpy' f kłłąt gpeg" kp" mpi " czku" mpi y u" dgw ggp" y g" tcpf qo k gf" i tqwr u" qh' uecr j qkf u" y cu" hqwpf 0' Cf f kkqpcm{." pq" uki pkłkecpy' f kłłąt gpeg" kp" ukłłpguu" cv' y g"  $3222^{y}$ " e{eng" dgw ggp" f kłłąt gpv" uetgy " ngpi y u" y cu" hqwpf " \*Hki wtg" 5+0' Cm' ur geko gpu" y kj " 3: o o " cpf" 460 o " uetgy " hzcykqpu" y gt g" cdng" vq" y kj uvcpf" e{enke" mcf kpi ." j qy gxgt" 3" ur geko gp" hkzgf " y kj " c" 320 o " uetgy " hckrgf " f wł.pi " e{enke" mcf kpi 0' Cu" c" tguwnz" c" r tqzko cn' hcewtg" hkzgf " y kj " c" 320 o " uetgy " y cu" cdng" vq" y kj uvcpf ": 67" Õ' 568" e{engu0' Nqcf" vq" hckrwtg" y cu" uki pkłkecpw{" \*r >(27+" ko r cevgf" d{" uetgy " ngpi y " wkłk gf " hqt" hkzvłqp0' C" uki pkłkecpy' f kłłąt gpeg" \*r >(27+" kp" mcf" vq" hckrwtg" dgw ggp" c" 320 o " uetgy " cpf" 460 o " uetgy " y cu" hywpf." j qy gxgt" pq" uki pkłkecpy' f kłłąt gpeg" \*r ?(828+" qeewttgf" kp" mcf" vq" hckrwtg" dgw ggp" cp" 3: o o "cpf"460 o "uetgy "\*Hki wtg'5+0

Fixewukip<' Vj ku" uwf {" gzco kpgf " yj g" ghigev' qh" uetgy " ngpi yj "qp" dgpf kpi "uvkhhpguu" f wtkpi "e{enke" nqcf kpi "cpf "nqcf " vq"hcknwtg0'Vjg"tguwnu"qh''yjku"uwwf{"ujqy" yjcv"c"uetgy "yjcv" o czkokt gu" y g" ngpi y " \*460 o +" y ky kp" c" ur geko gp" y kjuvepfu" uki pkhkecpvn{"itgevgt" nqef" vq" heknwtg" yjep" e" uetgy "yj cv" ku" egpvgtgf "\*320 o +" y kyj "tgur gev" vq" yj g" htcewtg" ukvg0' Vj g" 320 o "uetgy "i ckpu" nguu" r wtej cug" kp" vj g" dqpg" qp" gkj gt" ukf g" qh' yj g" htcewtg" eqo r ctgf " yg" y g" 460 o " uetgy 0' J qy gxgt." y gtg" ku" pq" uvcvkuvkecm{" uki pkhecpv" f khigtgpeg" kp" nqcf " vq" hcknwtg" dgw ggp" cp" 3: o o " uetgy ." y cv' f qgu" pqv" o czko k g" ku" ngpi y " y kj kp" y g" ur geko gp." cpf " c" 460 o " uetgy =" y ku" eqwrf " dg" qeewttkpi " dgecwug" y g" 3: o o " uetgy " ku" o qtg" egpvgtgf " y ky " tgur gev' vq" y g" uetgy " eqo r ctgf " vq" y g" 460 o " uetgy 0'  $\overline{Q}$ wt" f cvc" eqp<br/>vtcf kevu" c" r tgxkqwu" uwwf {" yj cv" eqpvgpf u" yj cv" o czko k kpi " yj g" uetgy " ngpi yj " uki pkhkecpun{" qr vko k gu" y tkuv" dkqo gej cpkeu" cpf " htcewtg"

j genkpi "]5\_0

**Uki phliecpeg<'** Vj g" tguwnu" qh" y ku" uwuf {" y km" r tqxkf g" uwti gqpu" y ky " wughwn" kphqto cvkqp" y cv' y km" j gnr " y go " kp" f gvgto kpkpi " cp" qr vko cn" uetgy " ngpi y " hqt" y g" hkzcvkqp" qh" rtqzkocn" uecrjqkf" htcewstgu" wukpi" egpstcn" yjtgcfnguu" uetgy u0' Hkzcskqp" wktkj kpi "cp" 3: o o "uetgy "eqorctgf" vq" c" 460 o "uetgy " o kpkokj gu" yj g" tkum' hqt" kplwt {"vq" yj g" fkuvcn" tcfkswictskewncskqp"fwtkpi "uwti gt {0

#### Tghgt gpegu≺

]3\_" Tj go tgx"UL'gv'cn016pv'L'Go gt 'O gf 04233="6<60

]4\_" Vtwo drg'O "gv'cr0/L'Co gt "Uqe "Unit "J 0/4223="377/3930

]5\_" F qf f u'UF "gv'cn'L'J cpf "Uwti 'Co 0'4228="627/635"]6\_" O eEcnkurgt "Y X"gv'cn'JL'Dqpg"Iqkpv'Uwti 'Co 0'4225=94/" 99





Screw Length	Stiffness (N/mm)	Load to Failure (N)
10mm (n=5)	209.2±40.2	180.5±83.2 *
18mm (n=5)	220.9±55.6	319.0±95.4
24mm (n=5)	236.7±37.4	437.2±68.5 *

### S wcpvlilecvlqp'qh'Egmwrctls{ 'cpf 'Nkr qkf 'F gi gpgt cvlqp'vq'Cuuguu'Nqecrl{ gf 'F gi gpgt cvlqp'kp" T qvcvqt 'EwlhiVgpf qpu

Uej cwdrg. "IC<sup>3.4</sup>="O krrgt. "TO<sup>3.4</sup>="O wucj n "X<sup>3.4</sup>="F gdunk "TG<sup>3.4</sup>

30' Qtyj qr cgf ke 'Tqdqvkeu'Ncdqtcvqt {.'Rkvudwti j.'RC.

Kpvt qf wevkqp<' F gi gpgtcvkxg" tqvcvqt" ewhh" vgctu" ctg" c" eqo o qp"rtqdngo." chhġevkpi" i tgcvgt" yi cp" 52''" qh' yi g" i gpgtcn" r qr wrcykqp" ]3\_0' T qycyqt" ewhh" ygctu" o quy" eqo o qpn{" qeewt" kp" yj g" uwrtcur kpcwu" vgpf qp" pgct" yj g" kpugt kqp" ukvg" ]4\_0'Vj gtg"ku"c"j ki j "hcknxtg"tcvg"qh"tqvcvqt"ewhh"vgct"tgr cktu." cpf " y ku" hcknwtg" v{r kecm{" qeewtu" cv' y g" ypf qp/uwwtg" kpvgthceg" ]5\_0' D{" fgvgto kpkpi " mecnki gf" fkhhgtgpegu" kp" tqvcvqt" ewhh" vgpf qp" f gi gpgtcvkqp." uwti kecn" vgej pks wgu" ecp" dg" ko r tqxgf 0' Rcuv" uwuf kgu" j cxg" gxcnwcvgf " rqecrkt gf " vgpf qp" fgigpgtcvkqp." dww y gug uwwfkgu qpn{ hqewugf qp qpg nqecvkqp" kp" yj g" vgpf qp." uvej " cu" yj g" o gf kcn' gf i g" qh' c" ej tqpke" vgct" ]4\_0' Vj gtghqtg." vj g" qdlgevkxg" qh' vj ku" uwaf { " ku" vq" gxcnvcvg" nqecnkj gf" vgpfqp" fgi gpgtcvkqp" kp" o wn.kr ng" nqecvkqpu" d{" swcpvkh{kpi "egmwnctkv{" cpf" nkrqkf" f gi gpgtcvkqp." w q" ej ctcevgtkuvkeu" qh" vgpf qp" f gi gpgtcvkqp0' KV" y cu" j {r qyj gukt gf "yj cv" yj gtg" y qwrf "dg" o qtg" nkr qkf " f gi gpgtcvkqp" kp" yj g" uwrtcur kpcwu" yj cp" yj g" kphtcur kpcwu." cpf " y cv" y gtg" y qwrf " dg" o qtg" egmwrctkv{" kp" vgpf qpu" y ky " ej tqpke"vgctu"vj cp"kp"kpvcev"vgpf qpu0

Ogvj qf u≺' Gki j v' htguj /htq|gp" ecf cxgtke" uj qwrf gtu" y gtg" wugf " kp" yi ku" uwuf {0' Hqwt" uj qwuf gtu" y gtg" kpvcev" \*77" Ô' 34" {gctu+"cpf "hqwt" j cf "uo cm' vgctu" kp "y g"uwr tcur kpcwu" vgpf qp" \*92"Õ'; "{gctu+0'Vkuuwg"dkqru{"ucorngu"y gtg"vcngp"htqo "y g" cpvgtkqt" cpf" rquvgtkqt" ukfgu" qh' yjg" kpugtvkqp." o kf/ uwduwcpeg." cpf " o {qvgpf kpqwu" lwpevkqp" tgi kqpu" qp" yj g" uwrtcur kpcwu" vgpf qp0' Ucor ngu" y gtg" cnuq" vcngp" htqo " y g" kphicur kpcwu." kp" y g" uco g" tgi kqpu" cu" y g" uwr tcur kpcwu0' Hqt" ur geko gpu" y kyj " c" ej tqpke" vgct." uco r ngu" y gtg" cnuq" vcngp"htqo "yjg" ogf kcn"gf i g0'Vjg" ucor ngu" ygtg" hkzgf "kp" c" 32' " dwhigtgf " hqto crkp" uqrwkqp" hqt" cv' rgcuv' y tgg" f c {u0' Vj gp" uco r ngu" y gtg" ugevkqpgf " cv" c" y kempguu" qh" 7" Ùo " cpf " ew," npi kwf kpcm{." uvckpgf" y kj " j go cvqz { nkp" cpf " gqukp" \*J (G+" vq" xkuwcht g" vgpf qp" o qtr j qnqi {." cpf " ko ci gf " wukpi " c"nki j v"o ketqueqr g"y kj "c"42z"qdlgevkxg"ngpu"cetquu" y g"hwm" vgpf qp" y kempguu0' Cm' ko ci gu" y gtg" gxcnvcvgf " dcugf " qp" nkrqkf" fgigpgtcvkqp0' Vq" svcpvkh{" egmwnctkv{" cpf"

egmwnctkv{." y g" pwo dgt" qh" pwengk" kp" gcej " uco r ng" y cu" eqwpygf " wukpi " Ko ci gL" uqhiy ctg0' Hqt" nkr qkf " f gi gpgtcvkqp" cpcn{ uku." Ko ci gL" uqhiy ctg" y cu" wkrk gf " vq" f gvgto kpg" y g" r gtegpv' ctgc" qh" nkr qkf " f gi gpgtcvkqp" r gt" uco r ng0' C" w q/ y c{" CP QXC" cpf " c" r quvj qe" vguv' y cu" eqpf wevgf " vq" eqo r ctg" f gi gpgtcvkqp" dcugf " qp" nqecvkqp" cpf " y j gy gt" y g" ur geko gp" j cf " c" vgct." y kj " c" uki pkhkecpeg" qh' r " >" 20270' F gi gpgtcvkqp" eqo r ctkpi " y gtg" r gthqto gf "

#### wukpi "c"rcktgf "∀vguv0

Tguwunu K'Yjkng" vgpfqpu" ujqygf" xct{kpi" fgitggu" qh" f gi gpgtcvkqp." y gtg" y cu" pq" uvcvkuvkecn' uki pkhkecpeg" dgw ggp" y g" uwr tcur kpcwu" cpf " kphtcur kpcwu" dcugf " qp" nkr qkf "f gi gpgtcvkqp0' KV' y cu" cnuq" hqwpf " y cv" y gtg" y cu" pq" uvcvkuvkecn" uki pkhlecpeg" dgw ggp" kpvcev' cpf " ej tqpke" vgctu" dcugf " qp" egmwnctkw{." y wu" f kur tqxkpi " dqy " j {r qy gugu0' J qy gxgt." y gtg" y cu" c" uki pkhkecpv" kpvgtcevkqp" ghhgev" dgw ggp"nqecvkqp"cpf "y g"rtgugpeg"qh"c"vgct"hqt"egmwnctkv{" \*r?20238+0 Vj g" vgpf qp" o kf/uwduvcpeg" ui qy gf " uki pkhecpun{" o qtg" egmunctkv{" kp" ur geko gpu" y kj " ej tqpke" vgctu" y j gp" eqo r ctgf " vq" kpvcev" vgpf qpu." \*r?20246+" ]Hki " 3D." Hki " 4\_0' Vgpf qpu" y kyj " ej tqpke" vgctu" uj qy gf " ukipkhkecpun{" oqtg" nkrqkf" fgigpgtcukqp" kp" yjg" o {qvgpf kpqvu" lwpevkqp" y j gp" eqo r ctgf " vq" kpvcev" vgpf qpu"

#### \*r?20228+'']Hki ''3E.''Hki ''5\_0

F kuewuukqp<''Vj g" tguwnu" qh" yj ku" uwwf {" uj qy gf " yj cv" vkuuwg" f gi gpgtcvkqp" ku" ur tgcf " yj tqwi j qww" yj g" vgpf qp." cpf " ku" pqv" mecrki gf " vq" qpg" ur gekhke " mecvkqp0' Cu" nkr qkf " f gi gpgtcvkqp" y cu" xgt {" j ki j " hqt" vgpf qpu" y kyj " ej tqpke" vgctu" kp" yj g" o {qvgpf kpqwu" lwpevkqp." cpf " egmwrctkv{" y cu" j ki j " hqt" ej tqpke" vgctu" cv' yj g" o kf/uwduvcpeg." kv" ecp" dg" eqpenwf gf " yj cv" f gi gpgtcvkqp" cpf " yj g" r tgugpeg" qh' c" vgct" ctg" nkpmgf " hcevqtu0' Kpetgcugf " egmwrctkv{" ecp" dg" c " tguwnv" qh" kphrco o cvkqp." cpf " nkr qkf " f gi gpgtcvkqp" eqwif " dg" f wg" vq" o wueng" cvtqr j {." dqy " cuuqekcvgf " y ky " vgpf qp" kplwt {0' Dqy "



#### fkhhgtgpegu'kp'nqecnk gf 'f gi gpgtcvkqp0

qh" yj gug" f gi gpgtcvkqp" r ctco gvgtu" ecp" ugtxg" cu" c" r qvgpvkcn" tgcuqp" hqt" yj g" j ki j " uwwtg" r wn' qw' tcvgu" kp" tqvcvqt" ewhh" tgr cktu0' Vj ku" uwuf {" ku" uki pkhkecpv' dgecwug" j ki j " co qwpvu" qh" f gi gpgtcvkqp" ecp" tguwnv" kp" tgf wegf " o cvgtkcn' r tqr gtvkgu." y j kej "ecp" ngcf "vq" c" ej tqpke" vgct "cpf "hwt vj gt "vgpf qp" f gi gpgtcvkqp0' Vj ku" ku" enkpkecm{" uki pkhkecpv' dgecwug" uwti gqpu" uj qwrf " cxqkf " ctgcu" qh" r qqt" vkuuwg" s wcrkv{" y j gp" r gthqto kpi " c" tqvcvqt" ewhh" tgr ckt0' Cnj qwi j " y g" tguwnu" f kf " pqv" uwrrqtv" yjg" j {rqyjgugu." yjg" tguwnwu" ujqygf" yjcv" kpetgcugu" kp" nqecnk gf " vgpf qp" f gi gpgtcvkqp" ctg" pqv" nko kvgf " vq" yj g" o gf kcn' gf i g" qh' yj g" vgct0' Hwwvtg" f ktgevkqpu" hqt" yj ku" uwuf { "kpenwfg" gxcnwcvkpi "pwengk" uj crg" vq "fgvgto kpg"

#### 15\_" Rqpeg"gv"cn0Co "L'Ur qt ui'O gf 04235=63\*32+4478/830

#### ;0

]4\_" Ucpq"J "gv"cn0'L"Uj qwrf gt"Gndqy "Uwti 0'3; ; ; = \*8+₹96/"

Lcp=3; \*3+338/420

13 " [cocoqvq" L" Ujqwrfgt" Grdqy "Uwti 0' 4232"

#### Tghgt gpegı≺

#### tgr ckt0

**Uki pkłłecpeg<'** Vj tąwi j "wpf gtuvcpf kpi "y g" nkpmei g" dgw ggp" ej tqpke" tqvcvqt" ewhh" vgctu" cpf " mecnk gf " vgpf qp" f gi gpgtcvkqp." uwti kecn' vgej pks wgu" ecp" dg" ko r tqxgf " uq" vj cv' tgi kqpu"qh"j ki j "f gi gpgtcvkqp"ctg"pqv"wugf "kp"c"tqvcvqt"ewhh"

tqvcvkqp'xcnvgu'cv'cp'ceewtce{ "dgvgt'y cp'490

UWEEGUU'ETKVGTKC" Vjg" u{uvgo "ku" cdng" vq" tgwtp" vtcpuncvkqp" xcnwgu" cv" cp" ceewtce{" dgwgt" y cp3" o o " cpf"

#### eqwrf "dg"s wcpvkhkgf "xkc"c"5F "o qvkqp/vtcemkpi "u{uvgo 0

ceeqwpvkpi " hqt" crrtqzko cvgn{" 7/32' " qh' cm' cpmg" ur tckpu" cpf " 45' " qh" cm" cpmg" htcewtgu" ]3\_0' Vj g" o quv" eqo o qp" o gej cpkuo u" hat" u{ pf guo qvke" kplwtkgu" ctg" gzvgtpcn' tqvcvkap" cpf lqt" j {r gt/f qtukhrgz kqp" qh" y g" cpmg." dqy " qh" y j kej " o c{" f kutwr v" yj g" u { pf guo qvke" nki co gpvu" cpf " eqo r tqo kug" yj g" kpvgitkv{" qh" yig" fkuvcn" vkdkqhkdwnct" eqorngz0' Uwtikecn" hkzcykąp" ąh" yj g" hkdwrc" yą" yj g" ykdkc" cwgo r wu" yą" uvodkakt g" yj g" hkdwnc" cu" y gml cu" cmqy " y g" f kuvcn' nki co gpvu" vq" tgr ckt" rtqrgtn{0' Jqygxgt." ewttgpv' hkzcvkqp'' ogyjqfu'' ctg'' tgncvlx.gn{" kpghhgevlx.g." tguwn.kpi " kp" gzvgpfgf" tgeqx.gt{" vko gu"cpf "r cvkgpv"tgr qt vu" qh"cpmg"r ckp" cpf "f kueqo hqt v"]4\_0' Vj wu." yj gtg" ku" c" pggf " vq" gzco kpg" u{ pf guo qvke" kplwt kgu" kp" qtfgt" vq" kortqxg" uvuti kecn' hkzcvkqp" ogyjqfu" qh' yjg" fkuvcn' hkdwnc0' Rtgxkqwu" uwwfkgu" qh' u{pfguo quku" kplwtkgu" cpf" hkzcvkqp" o gyjqfu" j cxg" wugf" ur geko gpu" kp" y j kej " y g" nqy gt/ngi "ku" ugevkqpgf. "y gtgd { "fkutwr vkpi "y g"r tqzko cn" vkdkqhkdwnct" u{pfguo quku0'Kp" cffkxkqp." yjgug" uwwfkgu" wugf" o cpwcm{" crrnkgf" m,cfu" cpf" uvcvke" vtkcnu." y j kej " ctg" pqv" kf gcn"hqt" vguvkpi 0'Vj g"OLV"Oqf gn"HTU4232" tqdqvke" vguvkpi " u{uvgo " cv" y g" Qty qr cgf ke" Tqdq vkeu" Ncdqt cvqt {" ku" f guki pgf "hqt "8/FQH" dkqo gej cpkecn' lqkpv'' vguvkpi ." cpf "ku" ecr cdrg" qh''r tgekug" o qvkqp" cpf " f { pco ke" rqcf kpi 0' Gxgp" uq." yj g" tqdqvke" vguvkpi " u{ uvgo " ku" qpn{ " cdng" vq" vtceni' vkdkqvcnct" o qvkqp." uq" vq" svcpvkh{" vkdkqhkdwrct" o qvkqp" cp" gzvgtpcn" vtcemkpi " u{ uvgo " ku" pgeguuct { 0' Qpg" ghhgevkxg" vgej pks wg" qh" cpcn{| kpi " u{pf guo qvke" kplvt {" ku" d{" qdugt x kpi " 8/F QH" hkdwact" o qvkqp" y kyj " tgur gev' vq" yj g" vkdkc" kp" xctkqwu" kpvcev." kplwt{."cpf"hzcvkqp"oqfgnu"hqt"ecfcxgtke"urgekogpu0'Vjku" o qvkqp" ecp" dg" f gvgto kpgf " d{ " f ghkpkpi " eqqtf kpcvg" u{ uvgo u" hqt" yig" vkdkc" cpf "hkdwnc" cpf "hkpfkpi "yig" tgncvkqpujkru" dgw ggp" y qug" eqqtf kpcvg" u{uvgo u0' Vj ku" tgs wktgu" wuci g" qh" cp" gzygtpcn' vtcemkpi " u{uvgo " y j kej " ecp" f ghkpg" cpf " vtcem' yig" wkdkc" cpf "hkdwnc" cu" tkikf "dqfkgu" kp" c" yitgg" fkogpukqpcn" ur ceg0' Vj g" qdlgevkxg" qh" y ku" r tqlgev' y cu" vq" f gxgrqr " cpf " xcnkfcvg" cp" gzrgtko gpvcn" ugwvr" vjtqwij" y jkej" fkuvcn" vkdkqhkdwnct" cpvgtq/rquvgtkqt" \*CR+" vtcpuncvkqp." ogfkq/ nevgten" \*O N+" vtcpunevkqp." cpf "vtcpuxgtug" tqvevkqp" \*VX+"

Kplwtkgu" vq" yj g" cpmg" u{ pf guo quku" ctg" hcktn{ "eqo o qp."

KP VT QF WE VKQP

#### HKP CN'F GUR P

eco gtc"u{uvgo 0

<sup>3</sup>Qtyj qr cgf ke "Tqdqykeu"Ncdqtcyqt {. "F gr ctvo gpy"qh"Qtyj qr cgf ke "Uwti gt {. "F gr ctvo gpy"qh"Dkqgpi kpggtkpi . "Wpkxgtukk{ "qh"Rkwudwti j

RcttemL0J ci i gtv[3."Vj qo cu'TORigkhigt3.'Eqpqt"KOO vtr j {3."Iqugr j "ROT wuugn3.'Thej ctf 'GOF gdunk3.'O cecnwu'X0J qi cp3

#### Wikik kpi 'č'5F 'O qvkqp/Vt cenipi 'U{ uvgo 'hqt 'vj g'Dkqo gej cplecn/Cpcn{ uku'qh/F kwcn/Vklkqlkdwact 'Mkpgo cvkeu

RTQVQEQN *Tqdqvke" Vgukpi " Uugo <* Vy q" ugu" qh' o ctngt" vtkcfu" ctg" tki kf n{"o qwpvgf" vq" yj g" qy gt/ngi < qpg" qp" yj g" vkdkc." qpg" qp" yjg" hkdwnc0' Vjg" nqygt/ngi" ku" yjgp" tkikfn{" hkzgf" rgtrgpfkewnet" vq" vjg" nqygt" rnevg" qh' vjg" tqdqvke" vguvkpi" u{uvgo " \*OLV" O qf gn" HT Ū4232." Ej kpq." Lcr cp+" cpf " yj g" cpmg" ku" tki kf n{ " hkz gf " vq" c" r ncvg" eqppgevgf " vq" y g" tqdqvke" o cpkr wrcvqt" xkc" c" wpkxgtucn' hqteg lo qo gpv' ugpuqt" \*WHU." CVK F gnc" KR82" \*UK882/82+" Cr gz." P E+0' Qpeg" y g" ur geko gp" ku" r tqr gtn{ "hcuvgpgf " vq" yj g" tqdqv." c" O ketquetkdg" \*Oketquetkdg" OZ." Üqnwkqp" Vgej pqnqi kgu" Kpe0" Qgmc." OF +'ku''wugf ''vg''vguv'tki kf kv{ ''qh''y g''eqpuvtwev0 QrvkVtceml' Oqvkqp/Vtcemkpi " U(uvgo <" Chvgt" o qwpvkpi " cpf"

Vj g" hkpcn' gzr gtko gpvcn' ugwr " eqpukuvu" qh' c" eqo dkpcvkqp"

dgw ggp" y g" O LV" O qf gn' HT U4232" tqdqvke" vguvkpi " u{uvgo "

cpf " y g" Qr vkVtcem' 5F " o qvkqp/vtcemkpi " u{uvgo 0' Vj g" tqdqvke" vguvkpi " u{ uvgo " ku" vugf " vq" cuuwtg" tki kf kv{ " d{ " hkz kpi "

y g" my gt" mi " kp" r nceg" cpf " vq" r tgekugn{" gz vgtpcm{" tqvcvg" cpf" kpxgtv" y g" hqqv" d{" crrn{kpi " f {pco ke" hqtegu" cpf"

o qo gpvu0' Vj g" hkpcn' Qr vkVtcem' u{uvgo " ku" eqo r tkugf " qh' 8" kphtctgf/dcugf" eco gtcu" ukwcvgf" kp" c" j go kur j gtkecn'

hcuj kqp" ctqwpf " y g" ur geko gp." cp" Qr vkVtcem' ecnkdtcvkqp"

y cpf." i tqwpf " r ncpg." w q" f kuuko knct " tghngevkxg" o ctmgt "

vtkcfu." cpf" fki kkk gt0' Cm' Qr vkVtcem' ceeguuqtkgu" \*y cpf."

rncpg." octngtu." fkikktgt+" ctg" hkwgf" ykj" tghngevkxg"

o ctngtu" y j kej " cnqy u" y go " vq" dg" tgeqi pk gf " d{" y g"

kpkskcn' tki kf ks{ "vguskpi " qh' yj g" ur geko gp. "ukz" Qr vkVtcem' eco gtcu" \*Hrgz" 35." P cwtcrRqkpv' Kpe0" Eqtxcrrku." Qtgi qp+" ctg" ukwcvgf " ctqwpf " y g" ur geko gp" cv" xctkqwu" j gki j w" cpf " f gr ý u0' Co dkgpv'' nki j v'' kp'' ý g'' vguvkpi " ur ceg'' ku'' o kpko kt gf 0' Oqvkxg" \*Oqvkxg<Vtcengt." PcwtcrRqkpv' Kpe." Eqtxcmku." Qtgiqp+: "y g" ceeqor cp{kpi " o qvkqp/vtcemkpi " uqhvy ctg" r cemci g"qh"Qr vkVtcem"ku"dqqvgf."cpf "c"r tqlgev'ku"kpkvkcvgf 0' C" ecrkdtcvkqp" y cpf" \*EY O/472." P cwtcrRqkpv" Kpe0" Éqtxcmku." Qtgiqp+" ku" y cxgf " ctqwpf " y g" ur geko gp" cpf " y tqwi j qw' y g" f gukt gf " ecr wt g" xqnwo g" vq" ecnkdt cvg" y g" eco gtc"u{uvgo "cpf "tgpf gt"c"5F "ecr wtg"xqnvo g"kp"O qvkxg0' C" i tqwpf " r ncpg" \*EU/422" Ecnkdtcvkqp" Us wctg." P cwtcnRqkpv" Kpe0"Eqtxcmku."Qtgi qp+"ku"r rcegf "qp" y g" rqy gt"r rcvg" qh" y g" tqdqvke" vguvkpi " u{uvgo " vq" fghkpg" c" inqdcn" eqqtfkpcvg"

Vtcpurcvkqpcn' ceewtce{" y cu" gxcnxcvgf " d{" wukpi " c" my gt/" ngi "ucy dqpg" o qf gr0' Vj g" o qf grl y cu" o qwpvgf "d{"uetgy kpi " y g" vkdkc" kpvq" y g" tqdqvau" my gt" r rcvg" cpf " ewurqo " cpmg" dtceg." o kttqtkpi " o qwpvkpi " qh' cewcn' ecf cxgtke" ur geko gpu0' Vj tgg" dqnu" qh" xct{kpi " ngpi y u" y gtg" o gcuvtgf " y kj " f kcn'

### **TGÚWNVÚ** Vtcpurcvkąp

#### Qpeg" echdtcxkqp" qh" y g" tqdqvke" cpf " Qr vkVtceni' u{ uvgo u" ku" eqo r ngvg." y g" tqdqv" ku" cdng" vq" o qxg" y g" ur geko gp" y tqvi j " xct { kpi " f gi tggu" qh" gz vgtpcn'' tqvcvkqp" cpf " kpxgtukqp" cpf " y g" vtcemkpi " u{ uvgo " ecp" ghtgevkxgn{" s vcpvkh{" y g" vkdkcn' cpf " hkdwrct" o ctngt" vtkcf uø' o qxgo gpv0' F cvc" htqo " O qvkxg" ku" f ktgevn{" gzr qtvgf " cu" cp" gzegn'' ur tgcf uj ggv' kp" y g" hqto " qh" s vcvgtpkqp" vtcpuhqto cvkqp" o cvtkegu" hqt" y g" hkdwrc" cpf" vkdkc0' Hkngu" y kj " f cvc" hqt" f ki kk{ gt" echdtcvkqp" cpf" cpcvqo kecn' ncpf o ctmu" ctg" cnuq" gzr qtvgf " cu" ugr ctcvg" gzegn' ur tgcf uj ggvu0' Vj gug" f cvc" ugvu" ctg" vcmgp" kp" d{" ewuvqo " O C VNCD" eqf g." cpf" y tqvi j " c" ugtkgu" qh" vtcpuhqto cvkqp" o cvtkegu" y g" vtcpuncvkqp" cpf " tqvcvkqp" hqt" cp{" i kxgp" cpmg" uvcvg"ku'tgwtpgf0

#### Fcvc'Cpcn/uku

dg'uggp'lp'Hki wtg'40

u{uvgo "hqt" tghgtgpeg0' Vjg" fkuuko krct" o ctngt" vtkcfu" hcuvgpgf "vq" vj g" vkdkc" cpf "hkdwnc" ctg" vj gp" kf gpvkhkgf " y kvj kp" O qvkxgøu" 5F " ecr wtg" xqnvo g" cpf " ctg" f ghlpgf " cu" f kuvlpev" tki kf "dqf kgu" y kyj "f kurkpev" eqqtf kpcvg" u{uvgo u" \*Hki wtg" 3+0' Hqt" gcej " tki kf " dqf {." O qvkx g" cwqo cvkecm{" vtcemu" vtcpuncvkqpu" cpf "tqvcvkqpu" cpf "hqto wncvgu" gzrqtvcdng" vtcpuhqto cvkqp" o cvtkegu0' Chvgt" tki kf " dqf { "fghkpkkqp." cp" QrvkVtcem'fkikak{gt"ykaj" tghngevkxg"o ctmgtu"ku"ecnkdtcvgf" d{ "hkzkpi "ku" eqttgur qpf kpi "ecnkdtcvkqp" dnqen" \*Hki wtg" 4+" vq" y g"ny gt"r novg"qh"y g"tqdqv."r noekpi "y g"f ki kkk gt"vkr "kp"qpg" qh" y g" ecrkdtcvkqp" j qrgu" \*o ctrrgf " C." D." E." cpf " F+" cpf " o qxkpi " yi g" fki kkk gt" kp" c" j go kur j gtg" ctqwpf " yi g" dnqem" y j krg" nggr kpi " y g" vkr " hkzgf 0' Qpeg" ecnkdtcvkqp" ku" eqo r ngvg" y g" f ki kkt gt" ku" wugf" vq" f ghkpg" hqwt" cpcvqo kecn" r qukktqpu<" yjg" novgton" o omgqnvu." vkdkqvonot" lqkpv" egpvgt." vkdkon" wdgtqukv{." cpf" I gtf {u" wdgteng0' Htqo " y g" ncuv' y tgg" r qukkqpu." c" vkdkcn' cpcvqo kecn' eqqtf kpcvg" u{uvgo " ku" igpgtcvgf0'C" hkdwact" eqqtfkpcvg" u{uvgo "ku" gcukn{"fghkpgf" htqo "y g" vkdkcn' eqqtf kpcvg" u{uvgo "d{"uj khokpi "y g"qtki kp"qh" y g" vkdkcn' eqqtf kpcvg" u{ uvgo " \*y g" vkdkqvcnct" lqkpv' egpvgt+" vq" y g" vkr " qh" y g" novgton' o omgqnvu0' Vj g" f ki kkt gt" ku" uvkm' kp" ku" dgvc" uvci gu" qh" vguvkpi " cpf " ku" pqv" {gv" kpvgi tcvgf " kpvq" Qr vkVtcem' u{uvgo u." uq" ewuvqo " O C VNCD" \*O cvj Y qtmu" Kpe." O C+"eqfg"ku"wugf"vq"ecnkdtcvg" y g"fki kkk gt"cu" y gm"cu" f ghkpg" yj g" f ki kkk gtøu" nqecn' eqqtf kpcvg" u{uvgo " y j kej " ecp"

> Vj gtg" ctg" ugxgtcn" i gpgtcn' hcevqtu" y j kej " eqwf" j cxg" eqpvtkdwgf " vq" u{ugo " j qrknke" kpceewtcekgu0' Vj g" Qr vkVtcem' Hrgz" 35" eco gtcu" ctg" eqpvtcuv/dcugf." o gcpkpi " y gkt" ceewtce{" y km' ej cpi g" cu" yj g" rgxgn' qh' co dkgpv' rki j v' xctkgu0' Vj qwi j "ghhqtu" y gtg" o cf g" vq" nggr "co dkgpv' rki j v' vq" c" o kpko wo ." yj gtg" y gtg" ukm' uo cm' uqwtegu" qh' rki j v' r tgugpv' y j kej " o c{" j cxg" eqpvtkdwgf " o kpqt" gttqtu0' Cpqyj gt" hcevqt" vq" eqpukf gt" ku" eco gtc" qtkgpvckqp0' Qr vkVtcem' ecrewrcvgu"

#### Uqwtegu"qhGttqt

#### j ki j gt "y cp" y qug"f wtkpi "kpvgtpcn"tqvcvkqp" \*304 "cpf "2089+

Vj g" uweeguu" etksgtkc" hqt" vtcpurcvkqp" cpf" tqvcvkqp" tguwnu" y cu" ý cv" ý g"u{uvgo "cwckpgf"ceewtcekgu"uo cmgt" ý cp"3"o o " cpf" 4<sup>q</sup>." tgur gevkxgn{0' Vj g" cxgtci g" ecnewrcvgf" vtcpurcvkqpcn' ceewtce{" y cu" 207" o o ." cpf" cm" ý tgg" xcnwgu" y gtg" dqwpf gf" dgwy ggp" 205; " cpf" 207: " o o ." ý wu" ý g" u{uvgo " o gv" ý g" guvcdnkuj gf" etksgtkc" hqt" vtcpurcvkqpcn' ceewtce{0' J qy gxgt." kp" tqvcvkqp" ý g" u{uvgo " tgwtpgf" cp" cxgtci g" gttqt" qh' 408<sup>q</sup>." y j kej "ku"ncti gt" ý cp" ý g" ceegr vcdng" xcnwg"\*4<sup>q</sup>+" hqt" tqvcvkqp0' Cff kkqpcm{." Vcdng" 3" uj qy u" ý cv" ý g" gttqtu" f wtkpi " gz vgtpcn" tqvcvkqp" qh" ý g" hkdwr" \*70 " cpf" 408<sup>q</sup>+" y gtg" o wej "

#### FKEWUKQP

#### o gcuwtgo gpw'y cu'408q0

Cu" kp" y g" vtcpurcvkqpcn' ceewtce{" vguv." tqvcvkqpcn' ceewtce{" y cu" gxcnwcvgf" y kj " c" nqy gt/ngi " ucy dqpg" o qf gn' V j g" o qf gn' y cu" o qwpvgf" kp" y g" tqdqv' uko krctn{" vq" y g" vtcpurcvkqp" vguv0' Vj g" hkdwrc" y cu" f gvcej gf " htqo " y g" vkdkc." cpf " y g" f knvcn' j gcf " y cu" tki kf n{" uetgy gf" kpvq" y g" o gej cpkecn' cewcvqt" qh' y g" tqdqvke" vguvkpi " u{urgo 0' Vj g" tqdqvke" cewcvqt" y cu" y gp" o qxgf " y tqwi j " hyvt" cpi ngu" qh' tqvcvkqp<' 32<sup>q</sup>" gzvgtpcn' 7<sup>q</sup>" gzvgtpcn'' 7<sup>q</sup>" kpvgtpcn'' cpf " 32<sup>q</sup>" kpvgtpcn'' Vj g" tguvkpi " ucvg" qh' y g" kdkwc" y kj "tgur gev' vq" y g" vdkc" y cu" vcngp" cu" c" | gtq" tghgtgpeg" r qkpv' hqt" tqvcvkqpO' F cvc" y cu" eqmgevgf " uko wncpgqwun{" d{" y g" Qr vkVtcem' u{urgo " cpf " y g" tqdqvke" vguvkpi " u{urgo " hqt" y g" | gtq" tghgtgpeg" r qkpv' cpf " cm''hqwt" cpi ngu" qh''tqvcvkqp" \*Vcdrg"3-0'Vj g" cxgtci g" gttqt" kp" tqvcvkqp" y kj " tgur gev' vq" y g" tqdqvke" vguvkpi " u{urgo øu"

#### Tqvcvkqp

#### ecrkr gtu" cpf " r ncegf " ugs wgpvkcm{ " dgw ggp" y g" f kuvcn' vkdkc" cpf " hkdwrc0' Chwgt " r ncego gpv' qh" gcej " dqnv." y g" w q" dqpgu" y gtg" hkz gf " xkc" c" uetgy 0' Vj g" kpvcev' ucy dqpg" o qf grl y cu" vcngp"cu"c" | gtq" tghgtgpeg" r qkpv0'F cvc" y cu" eqngevgf "d{ " y g" Qr vkVtcem' u{ uvgo " hqt" kpvcev' cpf " y g" cf f kkqp" qh' uetgy u" 3." 4."cpf " 5" \*Vcdng" 3+0' Vj g" cxgtci g" gttqt" kp" vtcpurcvkqp" qh" y g" u{ uvgo " kp" tgncvkqp" vq" f kcn" ecrkr gt" o gcuwtgo gpvu" y cu" 20720 o 0

Figure 1. Reflective market	r

placement on tibia and fibula as

well as marker coordinate

systems.

Translation

+1<sup>st</sup> nut +1st and 2nd nuts

Reference (0 mm)

+ 1st, 2nd, and 3rd nuts



Figure 2. Digitizer and calibration block, as well as digitizer coordinate system.

OptiTrack

(mm)

Tracking System

0.01

5.20

10.40

16.33

Rotation

Reference

(0 Degrees)

10 External

5 External

5 Internal

10 Internal

Dial Caliper

Measurement

0.00

5.73

11.01

16.91

(mm)



Figure 3. Experimental setup for rotational accuracy test. The actuator can be seen blocking the fibular marker triad.

Robotic Testing System

0.0

-10.06

-5.06

5.05

10.05

(Degrees)

OptiTrack Tracking

0.0

-4.07

-7.07

6.20

10.62

System (Degrees)





qpn{ "kp"c"uvcvg"qh"gzvgtpcn"tqvcvkqp0Dqy 'xcnvgu"hqt"kpvgtpcn tqvcvkqp" hcm' y gm' y kj kp'' y g'' uveeguu'' etkgtkc0' Vj ku'' o c{ "dg" fwg"vq" yjg"rj {ukecn' cuugo dn{"qh'' yjg" tqvcvkqpcn' ceewtce{" vguv" \*Hki wtg" 5+0' Vjg" tgf "ekteng" jki jnki jvu" vjg" fkuvcn' vkr "qh" y g"hkdwnc" cwcej gf " vq" y g" o gej cpkech' cewwcvqt" qh'' y g" tqdqv' cu" y gml' cu" y g" o ctmgt" vtkcf" cwcej gf" unki j vn{" o qtg"

o qvkqp"qh"tghngevkxg"o ctngtu"d{"cuuko kncvkpi "cm"qh"ku"w q/" f ko gpukqpcn' eco gtc" hggf u" \*kp" y ku" ecug." ukz" hggf u+" cpf " gzvtcrqncvkpi "c" y tgg/f ko gpukqpcn' ur ceg "htqo "y go 0' Égtvckp" eco gtc" qtkgpvcvkqpu" ctg" o qtg" cf xcpvci gqwu" cpf" r tqxkf g"c"o qtg"ceewtcvg"ecr wtg"xqnwo g."cpf "gxgp"o kpwg" o qxgo gpu" qh" y g" eco gtcu" f wtkpi " qt" dgw ggp" ecr wtkpi " o ctngt" o qxgo gpvu" ecp" ungy " tguwnu0' Cffkkqpcm{." y g" tqdqvke" vguvkpi "u{uvgo "wugf "kp" yi ku"uvwf { "ku" s wksg" ncti g" cpf " uwttqwpfu" c" uki pkhkecpv' rqtvkqp" qh'' yjg" urgeko gp." yjkej " r tgxgpu" qtkgpvkpi " y g" eco gtcu" vq" i kxg" c" eqo r ngvg" 582<sup>q</sup>" xkgy "qh" y g" ur geko gp. "kg0' y g" kf gcn" eco gtc" qtkgpvcvkqp" hqt" dguv"tguwnu0'Vj gtg"ctg"cnuq"c"hgy "hcevqtu"y j kej "o c{"j cxg" eqpvtkdwgf "vq" kpceewtcekgu" kp" tqvcvkqp" ur gekhkecm{0' Qpg" hcevqt"y cu"y cv"y g"tqvcvkqpcn'czku"qh'y g"tqdqv'y cu"unki j vn{" cungy "htqo "y g" nqpi kwf kpcn' hkdwnct "czku0' Vj qwi j "y g" f khhġtgpeg" dgwy ggp" yj g" cz gu" y cu" uo cm " k/" o c{" j cxg" j cf " cp" ghhgev" qp" o gcuwtgo gpw0' J qy gxgt" d{" gzco kpkpi " y g" fkhhgtgpegu" dgw ggp" xcnwgu" hqt" y g" tqdqwle" cpf " qr wlecn" vtcemkpi "u{uvgo u." qpg" ecp" ugg" yj cv' ceewtce{" ku" s wkwg" my "

> ]3\_"Xcp"J gguv."V0"Kplwtkgu"vq"yjg"Cpmg"U{pf guo quku." IDIÜ.''4236< 8''825/350

#### TGHGTGPEGU

Uwti gt { "cv'y g"Wpkxgtukv{ "qh'Rkwudwti j 0

Vj ku" r tqlgev" y cu" uwr r qtvgf "lqkpvn{" d{" y g" F gr ctvo gpv" qh" Dkqgpi kpggt kpi " cpf " yjg" F gr ctvo gpv" qh" Qtyj qr cgf ke"

#### CEMPOY GFI O GPVU

#### tqvcvkqp"uj qwrf "pqv'dg"cr r nkecdng0

qpg" cv' o quv0' Vj ku" y cu" pqv' cp" kuuwg" f wtkpi " vtcpuncvkqpcn' vguvkpi " \*Hki wtg" 6+" ukpeg" vjg" tqdqv' y cu" qpn{" wugf " hqt" hkzcykąp" r wtr qugu0' Ūkpeg" yj g" pwo dgt" qh' eco gtcu" cdng" yq" qdugtxg"dqyj "o ctngt" ttkcf u" cv' cp{"i kxgp" tko g"j cu" c" f ktgev" ghhgev"qp" y g"ceewtce{ "qh" y g"u{uvgo ." y g"cewcvqt" drqenkpi " yj g" xkgy " qh' j crh'' yj g" cxckrcdrg" eco gtcu" o c{ " dg" yj g" f ktgev" ecwug"qh'ý g'j ki j "gttqtu"qdugtxgf "kp"gzvgtpcn'tqvcvkqp0 F wtkpi " vguvkpi " qh' cewcn' ur geko gpu." y g" cewcvqt " ku" kp" c" fkhhigtgpv" qtkgpvcvkqp." uq" yj g" gttqtu" qdugtxgf" kp" gzvgtpcn"

rtqzko cm{ "cmpi "y g"hkdwncøu" okfuj chv0'Fwtkpi "gzvgtpcn"

tqvcvkqp." kv" y cu" qdugtxgf " y cv" y g" cewcvqt" uj tqwf gf " y g"

hkdwrct" o ctngt" vtkcf øu" r ncego gpv" htqo " y tgg" qw" qh" y g" ukz"

eco gtcu0' F wtkpi " kpygtpcn' tqycykqp." ky' drqengf " y g" xkgy " qh'



- Ο · · · · ·
- u · · · · · · · · · ·
- · · · ·