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Wedge Calculation for Osteotomy. Are We Doingit Right? Trigonometry as a Tool for Calculationof Wedge Size Inosteotomies.

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Abstract
Genu valgum is commonest deformity encountered during childhood. In India bilateral genu valgum is generally seen due to deficiency disorders. Unilateral deformity usually occurs due to trauma, infection and rarely because of causes like congenital anomalies, skeletal dysplasia and genetic disorders etc.
Genu valgum in skeletally mature children is treated by corrective osteotomies but this has many unresolved aspects to it: 1) There is no reliable method to determine the size of wedge to be removed, which frequently results in over or under correction of deformity. 2) Secondly, there is no consensus on implant to be used for fixation in skeletally mature children.
We have tried to look into these aspects and found that a novel trigonometry based methodisreliable and easy method for calculation of wedge size to be removed during medial closingwedge osteotomy and inter alia all other osteotomies also. We have also found that fixation of osteotomies with appropriate size Kirschner wire supported by cast application on OT table is a very good, economic and reliable method with negligible complications and without the need for second surgery to remove the implant.

Keywords: *Genu valgum, Corrective osteotomies, Trigonometry, Medial closing wedgeosteotomy, Lateral closing wedge osteotomy, CORA, Paper tracing method, AutoCAD, Empirical method.*

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I. Introduction

Angular deformities around the knee in children are quite common, among these genu valgum is commonest. Majority of these deformities are physiological in nature, however some of these physiological and pathological deformities persist beyond adolescence and are a cause of concern for parents because of abnormal gait due to femoral valgus especially in a girl child[1].

Osteotomies had been used for decades to correct deformities of long bones. In 1875 Macewendescribed cuneiform osteotomy for the correction of genu valgumdeformity[2].

Osteotomies have been main stay of treatment for correcting these deformities not only inadults but also in children. In Genu valgum, the pathology lies in distal femur therefore the correction is done at the distal femur rather than the proximal tibia[3].

There are different distal femoral osteotomies described in literature but the commonly used are 1) Medial closing wedge osteotomy, 2) lateral opening wedge osteotomy[4].However medial closing wedge osteotomy has many advantages over lateral opening wedge osteotomy like direct bone apposition, construct stability, good bone healing, no need for bone graft and is therefore preferred[5][6].

In corrective osteotomies to get the desired outcome, measuring the amount of deformity, sizeof wedge and knowing the ideal site of osteotomy are crucial determinants. For measuring theamount of deformity (in degrees) and the site of osteotomy, the concept of CORA was introduced by Dror Paley. In many studies this concept has been proven correct for calculation of the amount of deformity and localizing the site of osteotomy[7].

Various methods of fixation of osteotomy like plate fixation[8], external fixator[9], kirschnerwire fixation with casting have been described. Osteotomy fixation with kirschner wiressupported bycast in adolescent children have shown good results. Fixation with plates and screws have many disadvantages like large exposure, higher implant and surgical cost, higherinfection rate, and need of second surgery for implant removal[10].

For wedge size calculations different methods like empirical 1 mm wedge size for1degreecorrection[11], paper tracing method[12], trigonometric method[13] and computerized method[14]have been described. Empirical method is unreliable, paper tracing is cumbersome andcomputerized method is expensive beside not being easily available while trigonometricmethod is reliable, easy and without any need for complex computerized software, and seemsto be better method.

Therefore we have embarked on this study to assess the accuracy of intra operative wedge size calculation by trigonometric method in medial closing wedge osteotomy, in patients of genu valgum.

II. Material And Methods

With prior institution ethical committee approval, 20 cases between the age of 14-18 years with genu valgum deformity having intermalleolar distance of more than 10 cm were included in the study (Fig 1). Patients with active metabolic bone disease previously operated knee for genu valgum, were excluded from study. All patients were thoroughly assessed clinically, radiologically, and relevant blood investigations were done. (FIGURE 1). All patients underwent radiological evaluation by CT scanogram of lower limbs to calculatethe tibio femoral angle and the site of osteotomy (by identifying CORA). (FIGURE 2)

The amount of deformity was measured radiologically on CT scanogram, as the angle formed between the anatomical axis of tibia and femur and after subtracting the average physiologicalgenu valgum angle of 7 degrees. (FIGURE 3)

Preoperative consent for operative procedure (medial closing wedge corrective osteotomy, and fixation using multiple kirschner wires (k wire/plating) was taken after explaining the procedure to patients and their attendants.

Patient was placed in supine position. A medial incision extending from lower pole of patella, to 2-3 fingers above patella was given after giving anaesthesia. The size of wedge to be resected was calculated intraoperatively using trigonometry, where a right angled triangle was assumed, with the base as width of femur and perpendicular as the wedge size to be resected. Base (widthof femur) was calculated intra-operatively by driving a graduated kirschner wire across the width of femur at the desired site of osteotomy after duly confirming under image intensifier(c arm). As per trigonometry $\tan\theta$ = perpendicular /base, already θ angle was calculatedpreoperatively from scanogram after correcting it for normal physiological genu valgum.

Perpendicular (wedge to be removed for deformity correction) is equal to $\tan\theta$xbase. Value of tan θ was taken from a ready-made trigonometric table. For example, if θ was 15 degrees andbase was 40 mm than perpendicular (wedge width) = Tan 15x 40(mm). (FIGURE 4).

The outlines of the wedge was marked upon the femur, with the cautery and then the divisionof the bone was done by drilling multiple holes which were joined by osteotomy and wedgeof desired size was removed. Apex of the wedge that is the lateral part of the cortex and theunderlying periosteum was left intact as it formed the hinge to stabilize the two fragments.

Osteotomy was then fixed with two appropriate sized kirschner wires from medial to lateral Femoral condyles crossing the osteotomy site with the wires ends kept outside the skin so as tomake removal easy. (FIGURE 5) Groin to ankle cast was applied immediately on the OT table.

Follow up of patients was done at 2 weeks, 1 month, 3 months and 6 months interval, and checkradiographs were done for assessing the bone union at 3 months. Kirschner wires were removedin OPD after union was ascertained on radiographs. Quadriceps strengthening exercises,active knee range of motion exercises were started. Weight bearing was initially started on partialweight bearing mode and later on converted to full weight bearing.

Full length lower limb scanogram was done after patient started full weight bearing, to assessThe correction achieved (FIGURE6). All patients regained their preoperative range of motion

In the operated limb by 20 weeks and achieved desired correction clinically. (FIGURE7).

III. Observations and Results

Table 1

Age distribution

Table 2

Most of the cases were between 14-16 years of age.

Union at osteotomy site

Table 3

In most of cases union achieved between 14 -16 weeks.

Valgus angle postoperatively

Table 4

Post operatively valgus angle achieved at knee joint after weight bearing allowed calculated from scanogram.

20 cases were taken for study. 9 cases (45 percent) were of 14 years age group, 4 cases were of15 years of age, 6 cases were of 16 years of age and 1 case was of 17 years of age. 65 percentof cases were females, and 35 percent were males. 65 percent cases had right side involvement.

Medial closing wedge osteotomy was done in all cases. Superficial infection was seen in1case which subsided with regular dressing. Post operatively valgus angle was measured fromscanogram of lower limbs after weight bearing was allowed. Post operatively in 50 percentcases weight bearing was allowed at 14 weeks after removal of kirschner wires and cast, 45percent patients were allowed to bear weight at 16 weeks. 5 percent cases were allowed weightbearing by 12 weeks after seeing the union of bone on radiograph. Overall 95 percent patientshad weight bearing between 14 to 16 weeks.

On comparing the post operative valgus angle with normal valgus angle value for knee, 95percent of our cases had achieved normal valgus angle of 7 degrees. This shows trigonometricmethod is accurate and reliable method of wedge size calculation in osteotomies.

IV. Discussion

Genu valgum is a uniplanar angular deformity most likely due to nutritional rickets. The child is usually brought for treatment at the time when deformity rapidly worsens following pubertal growth spurt. Since the remaining physeal growth is limited, therefore growth modulation maynot be a reliable modality of treatment in these patients. Hence correction by osteotomy is a bettermethod for correction in this adolescent age group of 14-17 yrs. Out of the two osteotomiesdescribed i.e. medial closing wedge osteotomy and lateral opening wedge osteotomy, medialclosing wedge osteotomy is preferred, because it has certain advantages like direct boneapposition of osteotomized cut surfaces, construct stability, reliable bone healing, and no needfor bone grafting[5][6].However it carries a disadvantage of slight shortening which is easilycompensated by shoe raise.

In our study we had chosen a study group of age between 14-18 years as there are less chances of

Recurrence of deformity after the corrective osteotomy in this age group and growth modulationis not a good option.

Most of the cases in our study were females probably because parents of young girls are moreperturbed about cosmesis and abnormal gait as a result of genu valgum which may affect theirmarriage prospects.

We performed medial closing wedge osteotomy in all 20 cases and found excellent results.All osteotomies united within 12 to 16 weekstime period post operatively. No non-union ofosteotomy was seen in 20 cases. Out of 20 cases performed superficial infection was seen in 1case, which subsided with regular

dressing. However 1cm of shortening was seen in one case,which is well described in medial closing wedge osteotomy.

In 2002 John A L also concluded that medial closing wedge distal femoral osteotomy has ahigher union rate and is a better technique as bone grafting is not required[15].

Nicholas C Detalin 2019performed a study on medial closing wedge osteotomy for distalfemur and concluded that there are certain advantages of medal closing wedge osteotomy likedirect bone apposition, construct stability, reliable bone healing, no need for bone graft[16].

Wedge size calculation is an important step in deformity correction, as wrong wedge size calculation can lead to under correction or over correction of deformity. There are various methods described in literature for wedge size calculation like: empirical method, paper tracing method, computer software based, trigonometric method.

The empirical method of one mm of base width of wedge, for one degree correction was given by Bauer, Insall and Koshino for high tibial osteotomy. In 2001 Milhako W Metal analyzed this method for lower limb corrective osteotomies and observed that empiricalmethod of Bauer results in lesser correction in wider bone[17]. In 2014 Cameron JI et al usedthis method preoperatively to calculate the amount of correction required to correct the valgusdeformity of knee using medial closing wedge osteotomy. They found that this method wasnot very reliable and this method was oversimplified and intraoperative fluoroscopic andvisual analysis of correction to neutral mechanical axis was not as accurate as they hadanticipated[18].

In paper tracing method, paper tracing of the bone from radiograph is traced on a paperpre operatively. Then tracings of osteotomy are made. Using scissors, the paper tracing of theradiograph along the osteotomy outline is cut.

In 2010 Paccola CAJ used paper tracing method to calculate the wedge size pre operatively forcorrection of genu valgum deformity. They opined that this method is very tedious and thereare very high chances of overcorrection of deformity[19].

In 2011 Kant SK et al calculated the wedge size to be removed in cubitusvarus deformitypreoperatively by making paper tracings. They observed that 96.2% cases of the cubitusvarus deformity correction had excellent-to-goodresults[20].

Many customized commercial computer-based preoperative planning software are available.In 2009 Jamali A, used computerized software for deformity correction and got accurateresults[21]. In 2009 Yung Z et al used computer aided software for preoperatively templatingthe deformity and got desired results[22] . In 2013 Chai W et al used computer aided design forcorrecting lower limb deformities and got the desired results[23]. This was corroborated byFilho ELR et al, in his study where he compared trigonometric method with computerizedsoftware method. The average lengths of the corrective wedges obtained by trigonometric, andAutoCAD were found to be accurate. However in India these software are not easily availableand are costly.

In 2006 Yang PB et al calculated the angle and wedge size to correct the fixed spine deformitiesby trigonometric method. They concluded that trigonometric method is simple and calculatesthe exact angle when the apex of the pedicle subtracting osteotomy on the sacral vertical line[24].Wylie JD in 2016 used trigonometric method for wedge size calculation in distal femoralosteotomy and got excellent postoperative outcomes, in terms of deformity correction andimprovedfunction[6].

In 2016 Warnock K M et al performed a cadaveric study to assess the accuracy of trigonometricmethod for calculation of wedge size in angular correction obtained for various wedge heightsand found it to be accurate[13]

In 2017 Sabbag OD et al performed a study on distal femoral medial closing wedge osteotomy in genu valgum deformity. They calculated the wedge size to be removed in medial closingwedge osteotomy by using trigonometric method and got the desired results[5].

Therefore wedge size calculation by trigonometric method is found to be a reliable andaccurate method. In our study of twenty cases using trigonometric method intraoperatively forwedge size calculation we could achieve the desired correction in 19 cases, and in one casewe achieved under correction of 3 degrees. So we are of the opinion that trigonometric methodis simple, highly accurate, cheap method requiring only basic mathematical

knowledge oftrigonometry. In this study, the accuracy of trigonometric method (used intra operatively forwedge size calculation) was evaluated by comparing the preoperative valgus angle and postoperatively valgus angle achieved after the correction. This study on 20 genu valgum patientsshowed that intraoperative use of trigonometry for wedge size calculation is statisticallysignificant with a p value of <0.001.

Another important aspect of performing osteotomies is the use of fixation device. Variousfixation devices have been described for fixing the osteotomy site. In 2019 Ranjan R et al intheir study on correction of genu valgum deformity opined that fixation with k wires and castis a simple, low cost procedure which gives good results[25]. Agarwal A in 2020 performed astudy on corrective osteotomy on post rachitic genu valgum in children. They performedsupracondylar V osteotomy on 17 limbs, and fixation was done with k wires and high groinabove knee cast with knee in full extension. They concluded that k wire fixation with cast is asimple non rigid method of fixation with excellent results in children[10].

In our study we fixed the osteotomy with appropriate size kirschner wires (number and size ofKirschner wires used according to age and built of patients) supported with high groin cast.Aroundthe world rigid fixation with plates and screws is used most commonly, but it has manydisadvantages like larger exposure, use of expensive implant, higher infection rate, and needfor second surgery for implant removal. Kirschner wire fixation supported with cast applicationis asimple, stable, low cost procedure. Out of 20 cases no case of non-union or delayed unionwas seen. The only complication was superficial pin site infection in one case. This make it auseful procedure for use in developing countries where cost is an important issue.

V. Conclusion

In our study we concluded that:

1) Calculation of CORA is an important step to know the degree of deformity and the siteof osteotomy.

2)Medial closing wedge osteotomy of distal femur is an appropriate method of correctionfor genuvalgum deformity in skeletally mature children as it provides direct boneapposition of two cutbony surfaces, has good construct stability, and doesn't needbone graft thereby resulting in reliable bone healing.

3)The intra operative use of trigonometric method for wedge size calculation in medialclosing wedge osteotomy for genu valgum patients is reliable and achieved the desiredresult in majority of cases (95 percent).

4)Fixation of osteotomy by appropriate size kirschner wires supported by high groin to toe cast application is a desirable method as it is low cost, operator friendly and doesnot require another surgery for removal of implant.

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